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National Defence
Research and Development Branch

Défense nationale
Bureau de recherche et développement

DREA CR 97/409

SOLAR HEAT REFLECTIVE COATINGS

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Canada

EXECUTIVE SUMMARY

Marine coatings for the hull and superstructure of naval vessels often exhibit relatively high solar absorption due to the dark colours required for visual camouflage. This results in high surface temperatures which reduce the comfort of the crew, increase cooling requirements and amplify the emission of thermal infrared radiation. Reducing the absorption of solar energy requires pigments which reflect strongly in the near infrared. In this project we identified pigments with enhanced infrared-reflective properties, and reformulated three of the most commonly-used CGSB marine colours to produce coatings with improved infrared reflecting properties.

Six variants were prepared for 1-GP-61, 501-109 light grey alkyd enamel. Reflectivity of the experimental formulations at 900 nm ranged from 55% to 81%, compared to 42% for the General Paint standard coating.

Two variants were prepared for 1-GP-200, 501-302 dark grey polyurethane anti-skid enamel. Reflectivity of the experimental formulations at 900 nm ranged from 39% to 44%, compared to 8% for the Tibbetts standard.

Four variants were prepared for 1-GP-200, 503-305 dark green polyurethane anti-skid enamel. Reflectivity of the experimental formulations at 900 nm ranged from 20% to 50%, compared to 6% for the Tibbetts standard.

The experimental coatings meet CGSB requirements for salt spray and accelerated weathering resistance.

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INTRODUCTION

This is the final report for ORTECH project J23-B004751, "Solar Heat Reflective Coatings", carried out for Defence Research Establishment Atlantic, Esquimalt Defence Research Detachment, under contract no. W7708-5-0088/01-XSA.

The project had two objectives:

1. To evaluate the infrared reflective properties of pigments which can be used to tint the current 1-GP-61 marine topcoat and 1-GP-200 non-slip deck coatings, and

2. To reformulate these coatings to enhance reflectivity in the wavelength range from 700 to 1100 nm using infrared-reflective pigments and by varying the TiO_2 particle size, while maintaining a colour match in the visible range.

EXPERIMENTAL PROGRAM

The work plan consisted of the following tasks:

1. Literature review and material acquisition,
2. Measurement of reflectance spectra for coloured pigments,
3. Preparation of CGSB-specified colour range and characterization of reflectance spectra,
4. Preparation of large particle size titanium dioxide pigments,
5. Measurement of physical properties,
6. Characterization of thermal properties by thermography.

Literature Review

The literature review is found in Appendix A.

Material Acquisition

Standard Coatings

CGSB-approved 1-GP-61 was obtained from General Paint (Vancouver, BC) and Matchless Inc. (St. John's, NF). CGSB-approved 1-GP-200 was obtained from Tibbetts Paints Ltd., (Trenton, NS). A complete listing of standard coatings, primers, resins, pigments and their suppliers can be found in Appendix B.

Pigments

Major pigment manufacturers were contacted and asked to supply samples of infrared-reflecting pigments appropriate to the colours we were attempting to match. The pigments are summarized in Table I. Some pigment manufacturers provided visible colour matches to each of the standard colours in their own pigment grades. While useful as starting points, these formulations were not exact, since slight colour differences inevitably arise from differences in grind equipment, grind formulation, and raw materials such as resin and dispersion additives.

Preparation of Pigment Dispersions

Each pigment was predispersed into Aroplaz 2502-ML-60 marine alkyd resin reduced with xylene (6:1) using a Dispermat high speed disperser at a speed of 5,000 rpm. The paste was ground to a Hegman fineness of 6.5 to 8 using a ball mill with 1 cm stainless steel ball media. The mills were rolled at 480 to 500 rpm for 18 hours on a roller mill. Bentone SD 3 was added to some pastes to prevent pigrnent settling.

Tint pastes for the urethane systems were prepared in the same way as those for the alkyd system with the only differences being that acrylic resin was used in

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Table I - Pigments and Suppliers

Manufacturer	Pigment	Type	Price ($/kg)
BASF	Paliogen Black L0084	Perylene	$210.00
	Paliogen Black L0086	Perylene	$210.00
Bayer	Red Oxide 130M	Iron oxide	$3.31
	Yellow Oxide 3910	Iron oxide	$3.42
Ciba-Geigy	IRGACOLOR Black 10333	Chrome iron nickel black spinel	$20.00
	IRGACOLOR Buff 10406	Chrome antimony titanium rutile	$11.00
	IRGACOLOR Green 10405	Cobalt chromite green spinel	$26.30
	IRGACOLOR Green 10342	Cobalt titanate green spinel	$41.15
	IRGALITE Green GLN	Polychloro-cooper phthalocyanine	$30.50
	IRGAZIN Yellow 3RLTN	Isoindolinone	$93.10
Ferro Corp.	V-700 Black	Chromium green/black hematite	$18.06
	V-9238 Blue	Cobalt chromite blue/green spinel	$59.77
	V-11674 Green	Chromium (III) oxide	$9.59
	V-11692 Green	Chromium (III) oxide	$9.59
	V-12600 Green	Cobalt chromite green spinel	$25.05
Harcros Pigments, Inc.	G 6099 Green	Chromium (III) oxide	$12.00
Harshaw	9885 Meteor Plus High IR Black	Iron chromite brown spinel	$25.75
(Engelhard Corp.)			
Shepherd Color Co.	Green 179	Cobalt chromite green spinel	$17.84
	Green 4	Cobalt titanate green spinel	$18.24
	Black 123	Chrome, iron oxides	$14.52
	Black 376	Chrome iron nickel black spinel	$18.15
	Yellow 195	Nickel antimony titanium yellow	$9.83
	Gray A8151	Mixed metal oxides	$0.75

place of alkyd resin, and talc was added before colour matching began.

It was noted that cobalt-based pigments (IRGACOLOR Green 10405, Ferro V12600, Shepherd Green 4 and 179) tended to gel on standing over a period of weeks. In discussions with the manufacturers of these pigments, it was felt that, since the cobalt in the pigment is non-reactive, the instability might be caused by trace cobalt contaminants. This instability should be kept in mind when using any of these pigments.

Dispersion formulas are given in Appendix C.

Particle Size Measurement

Selected pigment dispersions used to prepare matches to the 1-GP-61 alkyd were characterized for particle size using a Malvern Mastersizer. Full details can be found in ORTECH report no. 96-B21-U004955-1-115, Appendix D.

Coating Formulation

The resulting pastes were used to prepare masstone (Table II) and pastel (coloured pigment mixed with white, Table III) alkyd paints. Pigment concentrations were selected so that the paints would achieve hiding at approximately 1.0 - 1.5 mils dry film thickness.

Pigment colours are not completely additive. White normally reflects at close to 100% from 380 nm to 700 nm whereas black pigments completely absorb in this range. Therefore, it is expected that blends of black and white will produce reflectance curves which are the algebraic sum of the individual black and white reflectance values. In some cases (black and white) this is true, but it is not the case with coloured pigments. Addition of black to yellow produces green, not reduced reflectance in the yellow portion of the visible spectrum. Similarly, various undertone colours which are not noticeable in the masstone become

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apparent when colours are mixed with white. Therefore, it was believed that the behaviour of each pigment would be best understood by characterizing reflectance both in the masstone and in a pastel.

The pastel paints were prepared with a combination of 25% coloured pigment and 75% titanium dioxide.

The following pigment to binder ratios were used to produce the various test paints:

Pigment Colour	Masstone	White
Black	0.3	0.5
Brown	0.5	0.6
Blue	0.5	0.6
Gray	0.5	0.6
Green	0.5	0.6
Yellow	0.8	1.0

Table II - Clear Base Formula

Aroplaz 2502-ML-60	84.24
Xylene	15.16
NeoCem 250	0.15
Dri Rx	0.15
Nuxtra 12% cobalt	0.15
Exkin #2	0.15
	100.00

Table III - White Base Formula

Dispersion

Aroplaz 2502-ML-60	11.67
Xylene	6.22
Kronos NL 2102 TiO_2	35.01

Letdown

Aroplaz 2502-ML-60	46.69
NeoCem 250	0.10
Dri Rx	0.10
Nuxtra 12% cobalt	0.11
Exkin #2	0.10
	100.00

Colour matches for the polyurethane formulas were done in the same way as with the alkyd formulas except that acrylic dispersions were used in place of alkyd dispersions. Once the colour match was attained, the pigment to binder ratio of the experimental formula was adjusted to 17/100 for the dark grey and 20/100 for the green, and the addition of the isocyanate resin was calculated. When the final formula was made up, the acrylic vehicle and the tint pastes were added together and mixed under agitation until a uniform colour was attained. Polyethylene fibre and ground glass were added. The isocyanate resin was added and mixed under agitation until uniform.

Coating Application

R-48 steel Q-panels (Chemroy Canada) with a dull matte finish were used for application and testing work. Large panels (2' x 2') for thermography were 1/8" thick cold rolled steel. The panels were wiped with acetone followed by isopropyl alcohol.

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For the alkyd system, the panels were primed with General Paint 1-GP-48M alkyd primer reduced with xylene and sprayed to a dry film thickness of 0.9 - 1.1 mils. The alkyd topcoats were then reduced with xylene and sprayed to a dry film thickness of 1.0 - 1.2 mils.

For the urethane systems, the panels were coated with vinyl wash primer to give a dry film thickness of 0.3 - 0.5 mils. The vinyl wash primer was allowed to dry for 2 - 4 hours before applying zinc rich epoxy primer to a dry film thickness of roughly 3 mils. The primer was allowed to dry for a minimum of 20 hours before the topcoats were applied. Topcoats were applied with a brush or trowel to a dry film thickness of 30 - 50 mils, then dried for a minimum of 7 days.

Preparation of Visible Matches to CGSB 1-GP-12 Colours and Measurement of Reflectance Spectra

Colour matches provided by pigment manufacturers were used as starting points to produce visible matches to each of the three colours. Also, reflectivity data generated in the previous task were used to select pigments which were felt to have good potential. These pigments were then used to produce additional matches.

Preliminary colour matches were viewed in an Atlas CC-2 light booth (ORTECH MII No. B01341). It was noted that many of the colour matches were metameric; therefore, observations were made using the daylight light source.

Colour measurements were made using a HunterLab UltraScan spectrophotometer (ORTECH MII No. A09013) with the U.V. lamp off, specular excluded, D65 illuminant and 10° observer. Reflectance was measured over the wavelength range from 400 to 1100 nm (0.4 - 1.1 µm).

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Since our objective was to identify pigments capable of improving infrared reflectivity while giving a visible match, a relatively high ΔE specification of 2.0 was chosen for colour matching purposes. While this is not considered acceptable for commercial purposes, it was felt that if a particular blend of pigments could come this close to the standard, then the objective had been attained and further tinting would not be time effective.

Experimental 1-GP-61 formulations were also characterized for reflectivity in the range from 800 to 4,000 cm^{-1} using a Fourier Transform infrared spectrometer (see ORTECH report no. 96-J21-224-6, Appendix E).

Physical Testing

Each experimental coating was tested for resistance to salt spray, accelerated weathering, and adhesion to substrate. Coated steel panels were also submitted to EDRD for outdoor weathering.

Resistance to salt spray was done according to ASTM B 117-94, for 240 hours exposure, in a Singleton salt spray cabinet (MII No. B01415). Observations were made for corrosion and blistering. The panels were not scribed.

Accelerated weathering was carried out according to ASTM G 26-94, using the xenon arc weatherometer (MII No. A05142) for 360 hours exposure. Observations were made for colour and gloss change on the alkyd systems, and colour change on the polyurethane systems.

Adhesion to substrate was carried out according to ASTM D 3359-93, method A (crosscut method).

Thermography

In order to determine the approximate heat reflective effect of each coating, two foot square steel panels were coated with the standard coating and the experimental coating having the best infrared-reflectance curve for each colour. The panels were heated with a solar lamp. The temperature of the reverse side of each panel was measured with a thermocouple, and the infrared reflectivity was measured using infrared thermography.

Full details of the thermography procedures are found in ORTECH report no. 96-J53-M0199, Appendix F.

RESULTS

Reflectance and colour data for individual pigments can be found in Appendix G.

Formulations for each of the colour matches are reported in Appendix H. Spectrophotometric colour and reflectivity data can be found in Appendix I.

1-GP-61, 501-109

Six matches to 1-GP-61, 501-109 were prepared. The background to each of the matches is summarized as follows:

- Formulation 7222-55 was based on a match submitted by Ferro Corp.
- Formulation 7222-57 was based on the Ferro match, with BASF L0086 perylene black substituted for Ferro V700 chromium hematite.
- Formulation 7222-80 was also based on the Ferro match, with Harshaw 9885 iron chromite black substituted for Ferro V700, and Shepherd 179 cobalt chromite substituted for Ferro V12600 cobalt chromite.
- Formulation 7222-82 was based on a match submitted by Shepherd Color.

- Formulation 7222-68 was based on the Shepherd Color match, with A8151 mixed metal oxides substituted for Green 4 cobalt titanate and Chrome Black 376.
- Formulation 7222-87 was based on a match submitted by Ciba-Geigy.

Reflectivity curves comparing each of the matches to the General Paint standard are shown in Figure 1. Reflectivity at 900 nm ranges from 55% to 81%, compared to 42% for the General Paint standard. Substituting BASF L0086 perylene black for Ferro V700 chromium hematite (7222-57) gives considerable improvement in reflectivity compared with the Ferro match (7222-55), as well as the steepest increase at 700 nm, but at an increased cost per gallon. Substituting Harshaw 9885 iron chromite black for Ferro V700, and Shepherd 179 cobalt chromite for Ferro V12600 cobalt chromite did not enhance reflectivity, but did slightly reduce the cost.

Neither of the Shepherd matches nor the Ciba-Geigy match offered an improvement in reflectivity compared with the Ferro match, but Formulations 7222-68 and 7222-87 did give a significant reduction in cost. The reason for the difference in cost between the two Shepherd variations, 7222-68 and 7222-82, is based on the replacement of Green 4 cobalt titanate and Chrome Black 376 with A8151 mixed metal oxides. A8151 is a recycled pigment made up of batch residues, and therefore will suffer from slight batch-to-batch colour variations. However, it does show a good IR reflectivity profile, and is by far the least expensive pigment, at $0.75 per pound, of all those evaluated.

Figure 2 compares the formulations for effectiveness as a function of pigment cost. Effectiveness was defined as the percentage increase in reflectivity of the experimental formula compared to the standard at 900 nm. For Formulation 7222-57, the improvement in reflectivity would be (81.33 - 41.86)/41.86 x 100, or 94.3%. The indicated costs are based on raw materials only. There was no attempt to optimize pigment levels, and no extender pigments were used. The coatings were costed out using the following parameters:

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Pigment to binder ratio	66/100
Non-volatile content	64% - 65%
Weight per gallon	10.7.

Little variation in hiding properties was noted between the formulas.

In Figure 2, optimal performance comes at the top left, declining toward bottom right. While Formulation 7222-57 offers by far the best performance, cost may be an issue. Formulation 7222-68 provides reasonably good performance at minimal cost. Since thermography was carried out only on Formulation 7222-57, no quantitative correlation could be established between a coating's reflectivity and the effect it would have on substrate temperature. The effectiveness of each coating should therefore only be used as a guideline for selecting pigments.

1-GP-200, 501-302

Two matches were obtained to the dark grey anti-skid coating.

- Formulation 7222-123 was based on a blend of Shepherd 123 chrome oxide and BASF perylene black.
- Formulation 7222-126 was based on a modification of a match submitted by Ferro Corp.

Reflectivity curves comparing each of the matches to the Tibbetts standard are shown in Figure 3. The performance/price comparison is shown in Figure 4. The coatings were costed out using the following parameters:

Pigment to binder ratio	17/100
Non-volatile content	59.6%
Weight per gallon	12.6.

Table V
Accelerated Weathering Colour and Gloss Measurements for 1-GP-61 Formulations

Reference	Initial Colour	Final Colour	Difference	Initial Gloss (60°)	Final Gloss (60°)	Difference
General Marine 1-GP-61 601-109	L* 74.28 a* -6.11 b* 1.66	L* 74.79 a* -5.93 b* 0.64	ΔE 1.16 ΔC -0.37 ΔH 0.97	79.6	55.3	-24.3
7222-55	L* 73.03 a* -5.43 b* 0.21	L* 74.19 a* -5.52 b* -0.78	ΔE 1.52 ΔC 0.13 ΔH 0.98	81.5	68.3	-13.2
7222-57	L* 73.16 a* -6.22 b* 0.62	L* 73.32 a* -5.74 b* -0.72	ΔE 1.43 ΔC -0.46 ΔH 1.35	83.7	72.3	-11.4
7222-68	L* 73.32 a* -8.55 b* 2.40	L* 73.86 a* -8.38 b* 1.02	ΔE 1.49 ΔC -0.44 ΔH 1.32	82.5	43.5	-39.0
7222-87	L* 73.33 a* -6.84 b* 2.88	L* 74.23 a* -6.61 b* 2.45	ΔE 1.02 ΔC -0.37 ΔH 0.31	87.6	82.8	-4.8

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Table IV
Thermography Results

Coating	Standard	Experimental	Difference
1-GP-61, 501-109 7222-57	52.8°C	44.0°C	8.8°C
1-GP-200, 501-302 7222-123	70.1°C	62.6°C	7.5°C
1-GP-200, 503-305 7222-122	69.3°C	60.9°C	8.4°C

Physical Properties

None of the test formulations showed any sign of corrosion, blistering, or pitting after 240 hours salt spray exposure.

Results of the accelerated weathering testing are reported in Tables V and VI. None of the test formulations showed significant colour change. The gloss change of the 1-GP-61 formulations was less than that of the control, except for Formulation 7222-68. (Because of limited quantities of some of the required pigments, Formulations 7222-80 and 7222-82 were not tested for accelerated weathering resistance).

Results of adhesion testing to primer before and after accelerated weathering are reported in Table VII. The alkyd systems gave weak to acceptable adhesion. All of the polyurethane systems gave excellent adhesion to primer.

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Table V
Accelerated Weathering Colour and Gloss Measurements for 1-GP-61 Formulations

Reference	Initial Colour	Final Colour	Difference	Initial Gloss (60°)	Final Gloss (60°)	Difference
General Marine 1-GP-61 501-109	L* 74.28 a* -6.11 b* 1.66	L* 74.79 a* -5.93 b* 0.64	ΔE 1.16 ΔC -0.37 ΔH 0.97	79.6	55.3	-24.3
7222-55	L* 73.03 a* -5.43 b* 0.21	L* 74.19 a* -5.52 b* -0.78	ΔE 1.52 ΔC 0.13 ΔH 0.98	81.5	68.3	-13.2
7222-57	L* 73.16 a* -6.22 b* 0.62	L* 73.32 a* -5.74 b* -0.72	ΔE 1.43 ΔC -0.46 ΔH 1.35	83.7	72.3	-11.4
7222-68	L* 73.32 a* -8.55 b* 2.40	L* 73.86 a* -8.38 b* 1.02	ΔE 1.49 ΔC -0.44 ΔH 1.32	82.5	43 5	-39.0
7222-87	L* 73.33 a* -6 84 b* 2.88	L* 74.23 a* -6.61 b* 2.45	ΔE 1.02 ΔC -0.37 ΔH 0.31	87 6	82 8	-4.8

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Table VI
Accelerated Weathering Colour Measurements for 1-GP-200 Formulations

Reference	Initial Colour		Final Colour		Difference	
Tibbetts 1-GP-200 501-302	L*	29.39	L*	28.33	ΔE	1.09
	a*	-0.22	a*	-0.35	ΔC	-0.24
	b*	-2.29	b*	-2.02	ΔH	-0.16
7222-123	L*	32.86	L*	33.20	ΔE	0.37
	a*	1.22	a*	1.37	ΔC	0.14
	b*	-0.08	b*	-0.04	ΔH	0.05
7222-126	L*	35.29	L*	35.66	ΔE	0.40
	a*	-0.28	a*	-0.19	ΔC	-0.13
	b*	-2.26	b*	-2.13	ΔH	0.07
Tibbetts 1-GP-200 503-305	L*	28.79	L*	27.35	ΔE	1.99
	a*	-15.13	a*	-13.84	ΔC	-1.11
	b*	3.92	b*	4.38	ΔH	-0.80
7222-122	L*	33.21	L*	34.47	ΔE	1.35
	a*	-8.32	a*	-8.69	ΔC	0.47
	b*	3.81	b*	4.13	ΔH	-0.13
7222-124	L*	36.46	L*	37.37	ΔE	0.94
	a*	-15.39	a*	-15.45	ΔC	0.12
	b*	5.11	b*	5.32	ΔH	-0.18
7222-125	L*	32.72	L*	33.31	ΔE	0.60
	a*	-9.47	a*	-9.43	ΔC	-0.04
	b*	2.89	b*	2.91	ΔH	-0.02
7222-127	L*	34.43	L*	34.58	ΔE	0.23
	a*	-15.29	a*	-15.17	ΔC	-0.10
	b*	2.67	b*	2.80	ΔH	-0.15

Table VII
Adhesion to Primer

Reference	Before Weathering	After Weathering
General Marine 1-GP-61 501-109	4A	4A
7222-55	3A	3A
7222-57	2A	2A
7222-68	2A	3A
7222-80	3A	N/A
7222-82	3A	N/A
7222-87	4A	4A
Tibbetts 1-GP-200 501-302	5A	5A
7222-123	5A	5A
7222-126	5A	5A
Tibbetts 1-GP-200 503-305	5A	5A
7222-122	5A	5A
7222-124	5A	5A
7222-125	5A	5A
7222-127	5A	5A

Particle Size Measurement

The particle size distributions of seven pigments dispersed in alkyd resin were characterised using the Malvern Mastersizer. Since these dispersions were prepared several months prior to the measurements, it is possible that some flocculation had taken place, skewing the results high in come cases. The mean

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and median particle sizes are reported in Table VIII. Complete results are reported in Appendix D.

Table VIII - Pigment Particle Size Measurements

Pigment	Reference No.	Median Particle Size (μm)	Mean Particle Size (μm)
Shepherd Yellow 195	96-J23-7222-06B	1.04	1.49
Shepherd Gray A8151	96-J23-7222-08A	1.03	1.70
Harshaw 9885	96-J23-7222-09B	0.94	5.02[1]
BASF L0084	96-J23-7222-11B	4.82	6.21
Ferro V11674	96-J23-7222-21A	1.07	2.32
Ferro V700	96-J23-7222-29	1.81	2.07
Kronos 2102	96-J23-7222-100B	0.29	0.32

[1] The large difference between the median and mean of this dispersion is due to a small amount (~2.5%) of material>10 μm.

Chemical Synthesis of Titanium Dioxide via Sol-Gel Technology

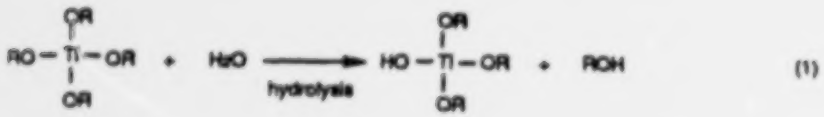
Background

Brady and Wake, in their paper "Principles and Formulations for Organic Coatings with Tailored Infrared Properties (Progress in Organic Coatings, 20 (1992) 1-25), elaborate on the physical principles of and the effect of pigment particle size on infrared reflectivity. They observe that, whereas commercial titanium dioxide pigments are manufactured with a particle size of 200 nm (the optimum value for scattering visible radiation with a peak intensity of 500 nm), larger particle sizes will be required to scatter the longer wavelengths of infrared radiation. Particles in the range from 378 to 504 nm would be required to scatter infrared radiation of 900 to 1100 nm. The objective of this phase of the project

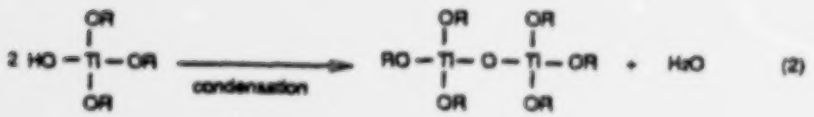
was to produce titanium dioxide having these larger particle sizes using a sol-gel technique, and evaluate their infrared reflecting properties in coatings.

Sol-gel methods fall into two broad categories, those based on polymerized alkoxides and those using colloidal sols. This project has used only the polymerized alkoxide process.

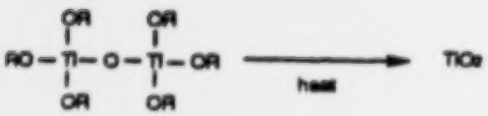
Sol-gel synthetic methods using polymerized alkoxides are basically decomposition-recomposition reactions. Metal alkoxides (metal-organic precursors) are partially hydrolyzed or decomposed, then are recombined by polymerization or condensation to form a metal-oxygen-metal bond. An example of this, using titanium isopropoxide to form titanium dioxide, is illustrated below.



(1)



(2)



(3)

R = Isopropyl -CH(CH3)2

For the preparation of fine titania particles, the alkoxide solution (sol) is emulsified in an immiscible solvent prior to polymerization. The sol droplets within the emulsion will each become the precursor to an individual TiO_2 particle. The ORTECH method used is as follows. The alkoxide is diluted in an anhydrous solvent (e.g. toluene, alcohol) to yield a sol. The sol is added to the stirred immiscible solvent to form the emulsion. When water is added polymerization takes place within each sol droplet. The droplets become particles containing an amorphous precursor of titania (Equations 1 and 2). The particles are collected by filtration and then converted to crystalline TiO_2 by firing (Equation 3).

The aim of this project is to control calcined particle size through control of sol droplet size and concentration of the alkoxide within the sol. The droplet size is a function of the interfacial surface tension between the sol and the emulsifying solvent.

Sol Preparation

The sols containing titania precursors were prepared by the following general procedure. Titanium isopropoxide was added to anhydrous solvents (e.g. toluene, isopropyl alcohol) and the mixture was stirred using a magnetic stirrer.

Powder Preparation

Emulsions were prepared by adding the sol, while stirring, to an immiscible, anhydrous solvent (usually acetonitrile). Water was then added to the emulsion to polymerize the alkoxide within the emulsion droplets. Stirring was continued for a few hours to allow sufficient time for water to diffuse to the centres of the particles to ensure complete polymerization.

Experiments to vary particle size of the titania particles included altering the sol composition, the solvent, the sol to solvent ratio and the order of component addition to the solvent.

Several powder preparation experiments were carried out. These included zvarying the following parameters:

- the sol to solvent volume ratio (at a constant sol composition)
- sol composition (at a constant sol to solvent volume ratio)
- stirring energy
- the alkoxide functional group (isopropoxide and isobutoxide)
- the solvent composition and its water content
- order of addition of components to solvent.

A total of 70 experiments were performed. Details are presented in Appendix E. A summary of these experiments and their results is presented in this section.

Some of the powders produced were fired for a short period of time at a high temperature to approximate flash calcining. The powders were placed into a furnace at 1000°C for 30 minutes. X-ray diffraction was carried out on one sample (6S-1). The analysis indicated the sample consisted almost totally of rutile TiO_2. Anatase TiO_2 was present at about the one percent level.

The powders produced were examined by scanning electron microscopy (SEM) to characterize their particle sizes and morphologies. The particle size of selected samples was also determined by a laser light scattering technique using a Malvern Mastersizer.

Overall observations can be summarized as follows:

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- The most significant variable affecting particle size was the solvent composition. The addition of a highly polar component (glycerol) to the solvent resulted in the production of large particles (ca. 1 μm, uncalcined). Alcohol was required in these sols to increase miscibility of the glycerol and acetonitrile.

- Another significant variable correlating with particle size is the solvent to sol ratio. Typically, smaller particles are observed with an increase in this ratio. Photomicrographs of powders prepared from solvent to sol ratios of 5:1 and 20:1 are presented in Figures 7 and 8, respectively. Further decreases in the solvent to sol ratio lead to the formation of extremely large, non-spherical particles. An example of these large, irregular particles is shown in Figure 9.

- Particle size distributions as measured by the Malvern laser diffraction method are a function of ultrasonication. The test method consists of dispersing the particles in ethanol, ultrasonication to assist in dispersing any loosely bound agglomerates, and analysis of the size distribution. The particle size analyses show a shift towards smaller particles as the ultrasonication period is increased. This suggests that the sample contains more tightly bound agglomerates and that these agglomerates are being broken apart by ultrasonication. Particle size distributions illustrating this effect are presented as Figures 10 and 11.

- Particle size distributions as measured by a Malvern Mastersizer are consistently higher than that observed by SEM examination. This is likely due to the presence of agglomerates. This effect is demonstrated in Figures 12 and 13.

The powder preparation technique that was most likely to yield TiO_2 powders of the desired particle size range (300 to 500 nm) used a 100% titanium isopropoxide sol. A photomicrograph of a powder prepared from this ternary solvent system is presented as Figure 14.

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The solvent employed is a ternary mixture of acetonitrile, glycerol and isopropyl alcohol. Several experiments were carried out to optimize the ratio of the solvent components required to achieve large (ca. 1 μm uncalcined), discrete particles. Low levels (ca. 33%) of acetonitrile tended to yield large, fused particles. The morphology shifted to smaller, more discrete particles as the acetonitrile level was increased and the levels of glycerol and isopropanol were reduced. Addition of the glycerol to the solvent after the sol, but before the water, led to the formation of reasonably large (ca. 0.8 μm, uncalcined), discrete particles. A photomicrograph of this powder is presented as Figure 15. However, the stability of this system was uncertain since large lumps were also formed during powder preparation and small modifications in the solvent composition yielded large differences in particle morphology.

Limited experiments employing organic titanates to modify interfacial tension between the sol and the emulsifying solvent did not improve particle morphology.

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CONCLUSIONS

Three CGSB marine colours were reformulated to enhance infrared-reflecting properties.

Six variants were prepared for 1-GP-61, 501-109 light grey alkyd enamel. Reflectivity of the experimental formulations at 900 nm ranged from 55% to 81%, compared to 42% for the General Paint standard coating.

Two variants were prepared for 1-GP-200, 501-302 dark grey polyurethane anti-skid enamel. Reflectivity of the experimental formulations at 900 nm ranged from 39% to 44%, compared to 8% for the Tibbetts standard.

Four variants were prepared for 1-GP-200, 503-305 dark green polyurethane anti-skid enamel. Reflectivity of the experimental formulations at 900 nm ranged from 20% to 50%, compared to 6% for the Tibbetts standard.

The experimental coatings meet CGSB requirements for salt spray and accelerated weathering resistance.

Some success was achieved in the sol-gel preparation of titania particles of the desired particle size range (0.3 to 0.5 μm). However, the obstacle of producing sufficiently large particles that are not fused together was not fully overcome. The systems investigated produced either particles that were large and fused together or small and discrete.

David Hacker
Manager
Coatings & Adhesives

Kam Aite
Manager
Materials Technologies

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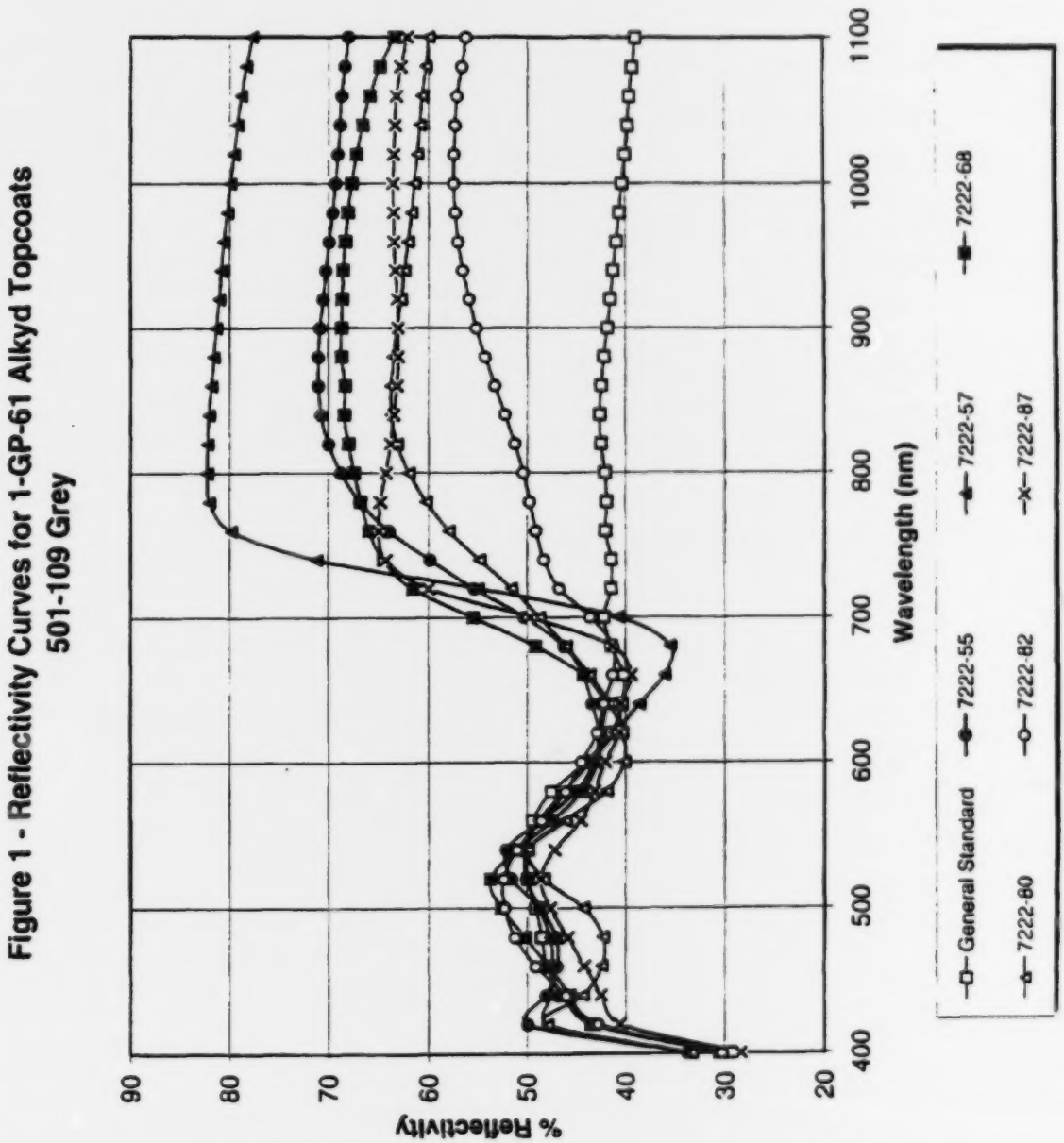

Figure 1 - Reflectivity Curves for 1-GP-61 Alkyd Topcoats 501-109 Grey

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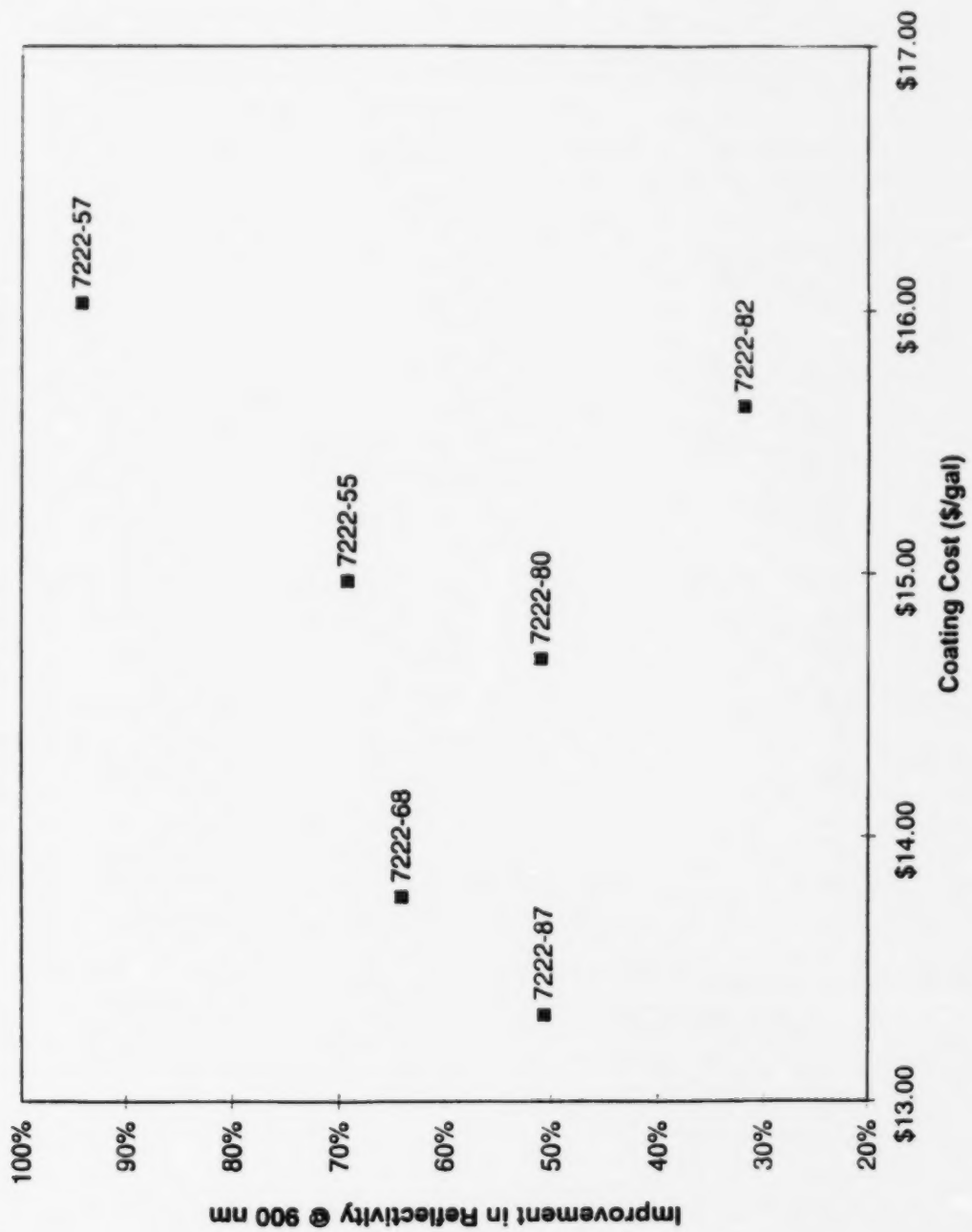

Figure 2 - Performance/Price Comparison for 1-GP-61 501-109 High-IR Reflective Coatings

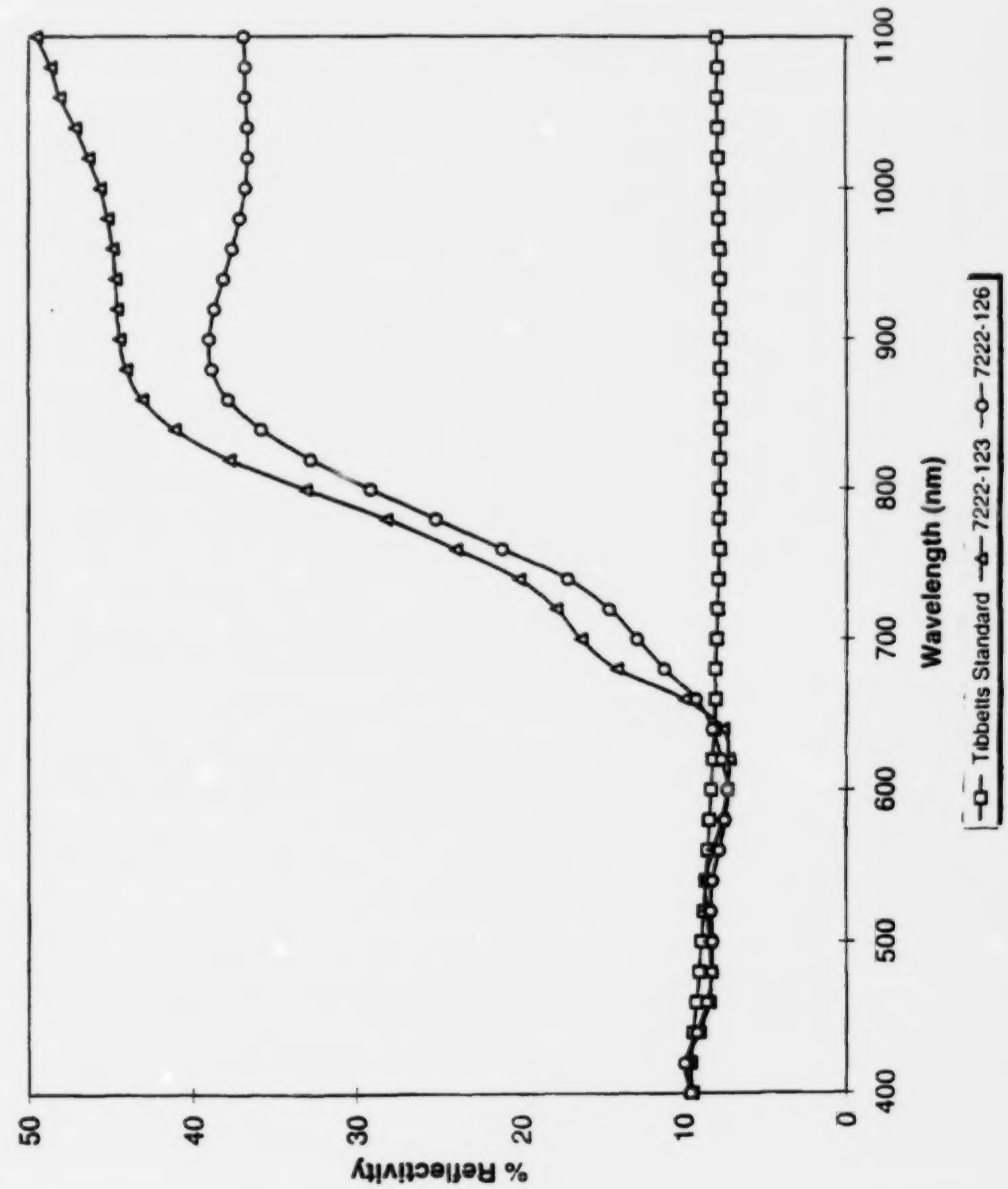

Figure 3 - Reflectivity Curves for 1-GP-200 Polyurethane Topcoats 501-302 Grey

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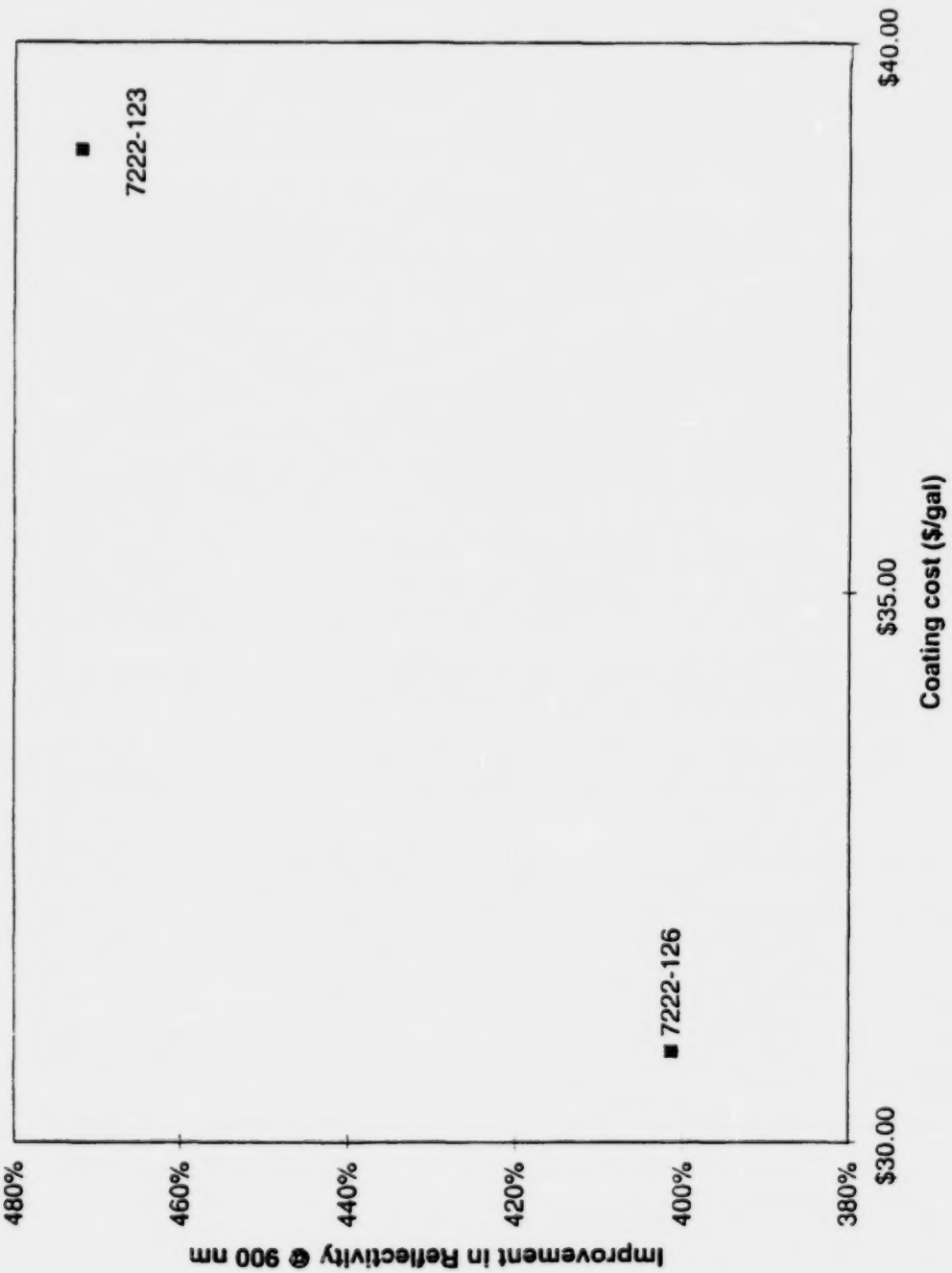

Figure 4 - Performance/Price Comparison for 1-GP-200 501-302 High-IR Reflective Coatings

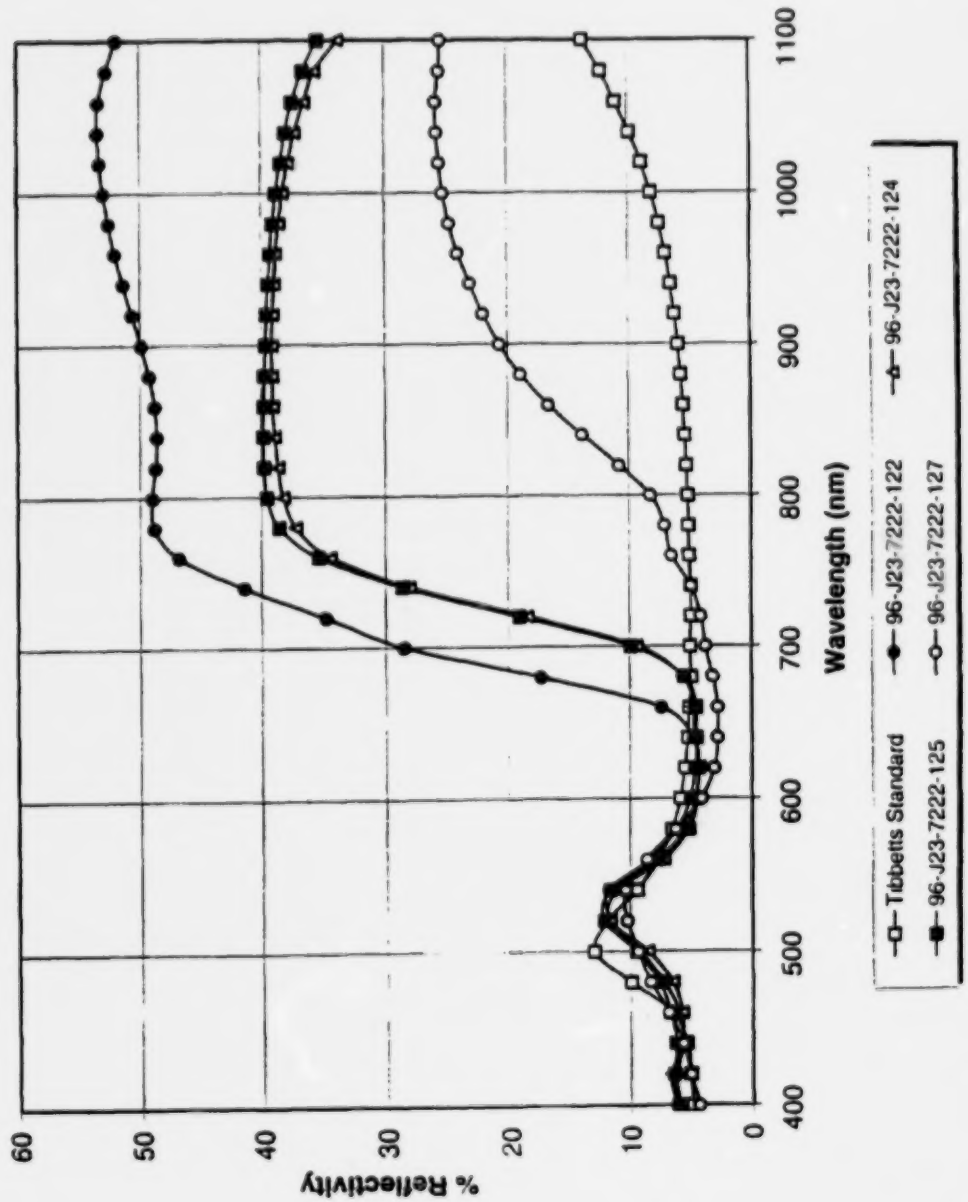

Figure 5 - Reflectivity Curves for 1-GP-200 Polyurethane Topcoats 503-305 Green

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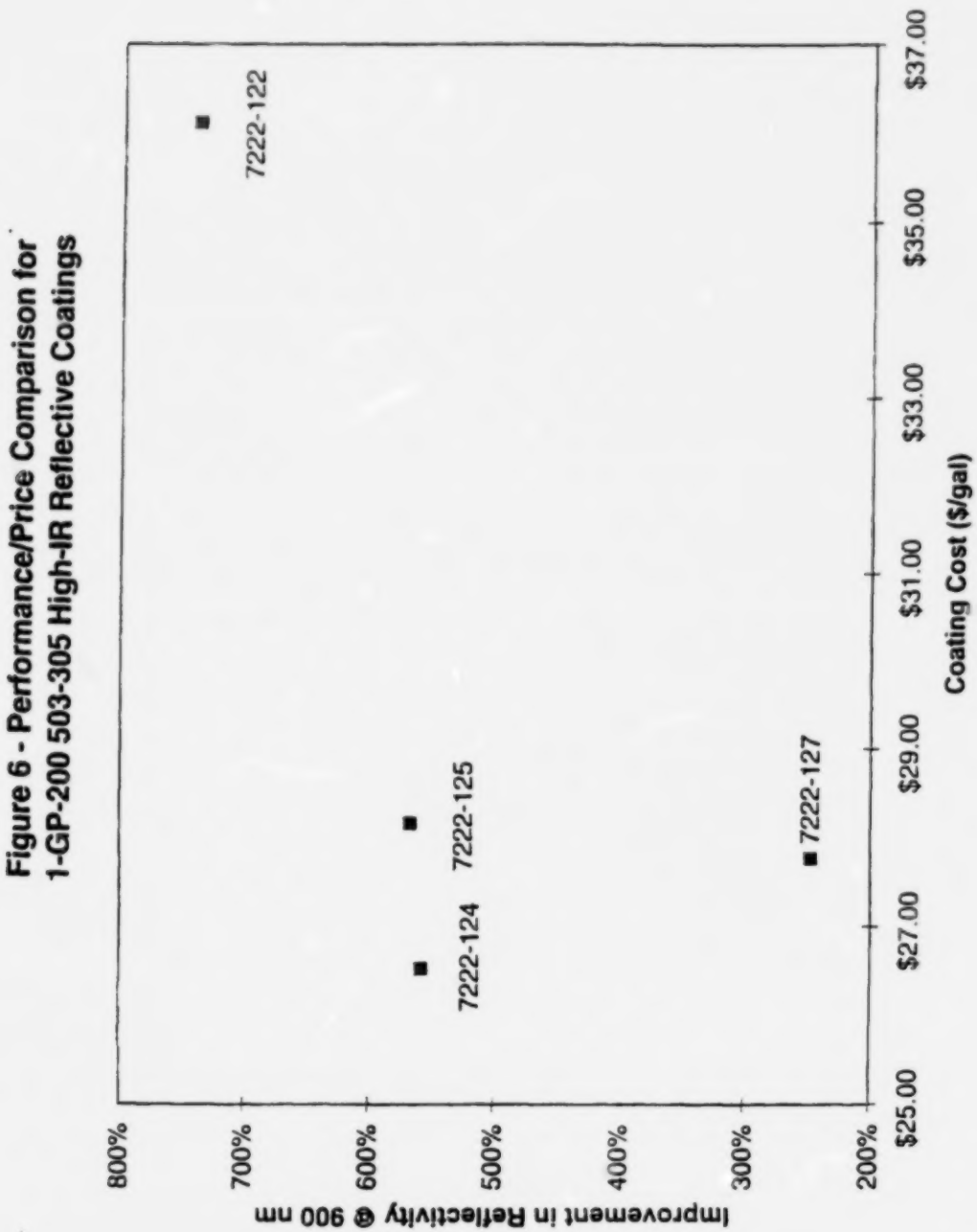


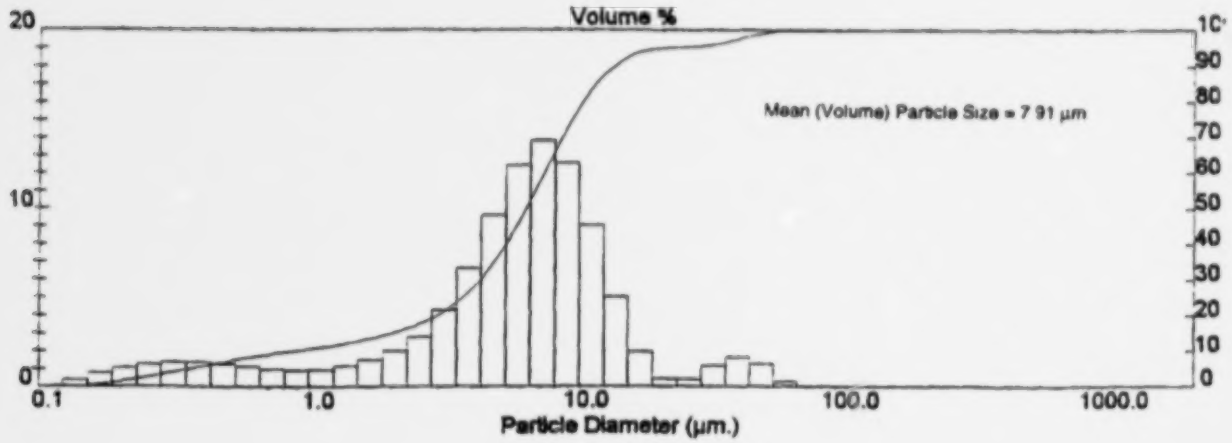
Figure 6 - Performance/Price Comparison for 1-GP-200 503-305 High-IR Reflective Coatings

Figure 7: Photomicrograph of TiO_2 precursor powder (20S-6) prepared using a solvent to sol ratio of 5:1. Magnification: 10,000X.

Figure 8: Photomicrograph of TiO_2 precursor powder (23S2-1) prepared using a solvent to sol ratio of 20:1. Magnification: 10,000X.

Figure 9: Photomicrograph of large, irregular TiO_2 precursor particles (26-4) prepared using a solvent to sol ratio of 1.1. Magnification: 5,000X.

Figure 10: Particle size distribution* of TiO_2 precursor powder (23S2-1) prior to ultrasonication.



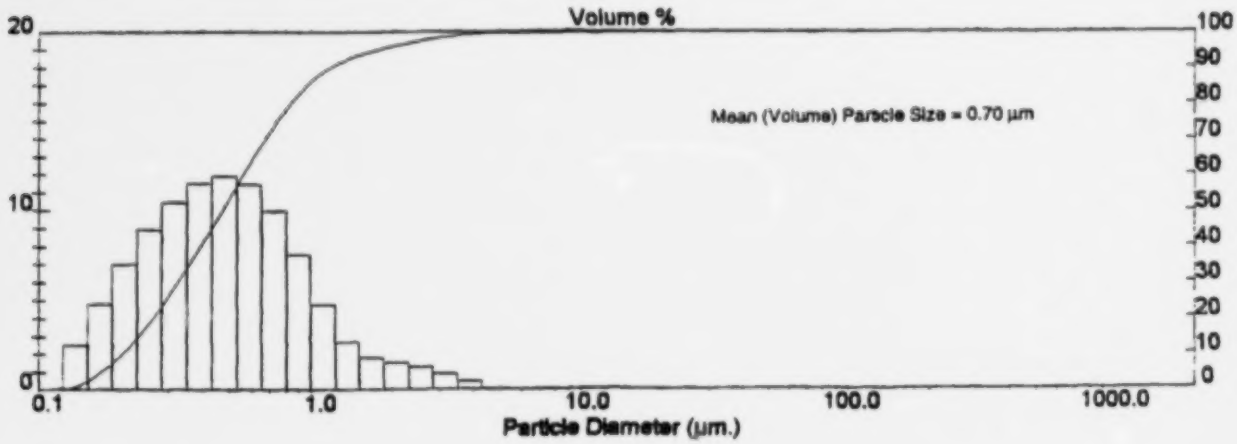


Figure 11: Particle size distribution* of TiO_2 precursor powder (23S2-1) after ultrasonication.

* Fraction above 80 µm not analyzed.

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Appendix A
Literature Review
(5 pages)

Literature references pertaining to infrared-reflective coatings fell into three categories: military reports, patents, and journal articles.

Military Reports

H.H. Sandler, in "Development of a Low Cost Solar Heat Reflecting and Low Visibility Coating" (U.S. Army CCL Report No. 178, March 1965), discusses the development of an experimental low cost green solar reflectant and low visibility coating for use on missile systems. A chrome oxide green pigment was used in place of the standard cobalt titanate in an alkyd paint system (TT-E-516). The experimental enamel had a 2 - 3°F advantage over the conventional coating.

R.B. Randall, in "Crew-Compartment Temperatures: The Effects of a Solar-Heat Reflecting Paint" (U.S. Army Technical Note 4-66), discusses a study to evaluate an olive-drab enamel that reflects solar heat. The evaluation compared temperatures inside two M113 Armored Personnel Carriers: one painted with the reflecting paint and the other with a conventional lusterless olive-drab finish. Over a five day period, measurements at five locations on each APC revealed that temperatures were lower in the vehicle treated with the reflecting paint.

M. Cohen and J.P. Doner, in "Infrared Reflectance Spectra for Selected Paint Pigments" (U.S. Army CCL Report No. 293, July 1971) present data on the near infrared reflectance spectra, 0.6 - 2.0 micron region, for 89 pigments in a wide range of colours. Both organic and inorganic pigments were selected for low infrared absorption and possible use in the design of military coatings with controlled infrared reflectance.

J.R Aronson, in "Modeling the Infrared Reflectance and Emittance of Paints and Coatings" (U.S. Army Research Office Report No. 14076.2-C, Jan. 1982), reports the results of a research program covering an investigation of the use of a theory of the reflectance and emittance of particulate materials as an aid to improving the camouflage properties of various substances. The objective was

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to produce improved coatings for military equipment, particularly in the thermal infrared region but also in the region of the near infrared near 1 micron. The report shows that the theory of reflectance or emittance of particulate materials can be successfully modified so as to apply to paints and coatings of military interest to predict the optical properties of proposed new coating systems, providing that optical constants for the components are available.

L.V. Wake, in "Principles and Formulation of Solar Reflecting and Low Infrared Emitting Coatings for Defence Use" (Australia DOD MRL Technical Report MRL-TR-89-2) describes how the near infrared reflectance of paint schemes may be increased by replacing dark pigments which are highly absorptive in the visible and infrared regions with visually similar pigments with low infrared absorption. On exposure to sunlight, these low IR absorbing pigments reduce heat buildup and thermal infrared signature. The report covers the formulation of coatings to reduce heat buildup, prolong service life and control IR emission from Defence equipment.

L.V. Wake, in "Development and Evaluation of a Near Infrared Reflecting and Low Visibility Paint Scheme for RAAF P-3C Orion Aircraft" (Australia DOD MRL Technical Report MRL-TR-93-35) discusses the development and trialling of a tactical, low visibility paint scheme for RAAF P-3C Orion Aircraft. The paint was formulated in grey colours using solar heat reflecting pigments to reduce overheating problems which had resulted in the abandonment of an earlier camouflage trial. Evaluation showed that the increased in heat load by using the solar heat reflecting paint scheme was 0.53 kW compared with 1.7 kW for conventionally formulated grey paints.

Patents

German patent specification no. 1,281,871 (July 1955) claims a pigment comprising an infrared reflective inorganic base material coated with at least one layer of an infrared penetrable organic dye wherein the inorganic base material

comprises the sulphides, selenides, and tellurides of elements of the second group of the periodic table.

U.S. patent no. 3,577,379 (May 1971) describes a dark coloured coating of high solar heat reflectance utilized to minimize heat build-up in the interior of objects exposed to sunlight comprising a mixture of pigments having a high infrared reflectance such as quinacridone red, carbazole, dioxazine, and titanium dioxide in combination with pigments such as lead chromate, molybdate orange, and phthalocyanine blue in order to obtain an acceptable colour match.

U.S. patent no. 3,591,400 (July 1971) describes a heat-reflective fabric that includes a thin continuous layer of partially overlapping reflective flakes supported on a layer of elastomeric material.

U.S. patent no. 4, 624,710 (Nov. 1986) claims an inorganic pigment having high reflectance in the infrared range when blended into a polyvinyl chloride resin, said pigment prepared by cocalcining a mixture consisting essentially of the oxides of chromium and iron in a weight ratio of approximately 2.5 to 3.5 parts of chromium to 1 part of iron.

European patent application no. 86109493.6 (Nov. 1986) relates to an azo compound and a coloured composition containing the azo compound, and more specifically to an infrared reflective coloured composition having higher infrared reflective properties compared with materials coloured or pigmented by a conventional black pigment such as carbon black and to a coloured composition having infrared reflection characteristics similar to green plants and hence being useful as a camouflaging material.

U.S. patent no. 5,006,175 (April 1991) relates to brown rutile pigment compositions and more particularly to such compositions comprising a major amount of titanium having a high reflectance in the infrared range.

Journal Articles

C.F. Pickett, in "Solar Heat Reflecting Coatings" (Society of Automotive Engineers, International Automotive Engineering Congress, Detroit, Mich., January, 1969) discusses work done at the U.S. Army Coating and Chemical Laboratory, Aberdeen Proving Ground, indicating that some pigments are better than others in reducing heat buildup on painted surfaces from solar radiation. Solar heat reflecting properties can be controlled by the selection of pigments in both the under and topcoats. This is possible because the reflectance or transparency of pigments is not the same in the visible and IR range.

"Infra Red Reflectance of Pigments in Surface Coatings" (Labdev J. Sci. Tech., Vol. 10-A 3-4, July-Oct 1972) reviews the effects of various pigments on infrared reflectance of coatings in the 0.7 - 1.5 micron range with a view towards developing IR camouflage coatings. Follow up to this work is reported in "Infra Red Reflectance of Pigments in Surface Coatings by Spectrophotometric Method" (Labdev J. Sci. Tech., Vol. 11-A 3-4, July-Oct 1973) which describes the measurement of reflectance in the 0.8 - 2.5 micron range.

R. Pipoly, in "Camouflage - A General Discussion" (Polymers Paint Colour Journal, Vol 179, No 4238, May 31, 1989) discusses the spectral reflectance requirements for pigments to simulate the appearance of chlorophyll in the 600 - 900 nm range.

"The effect of pigments in formulating solar reflecting and infrared emitting coatings for military applications" (L.V. Wake, J. Oil Colour Chem. Assoc., Vol 73, No. 2, 1990), summarizes the work reported in Australia DOD MRL Technical Report MRL-TR-89-2.

In "Principles and formulations for organic coatings with tailored infrared properties (Progress in Organic Coatings, 20 (1992) 1-25) R.F. Brady and L.V. Wake elaborate on the physical principles of infrared reflectivity and the

requirements for pigments, resins, and solvents to produce coatings having desirable reflectivity properties. Methods of formulating coatings having optimal infrared reflectance properties for various environments, e.g. desert, forest, or ocean environments, are described, and sample coating formulations are given.

P. Berdahl, in "Pigments to Reflect the Infrared Radiation From Fire" (Journal of Heat Transfer, Vol. 117, pg. 355, May 1995) describes how conventional paints transmit or absorb most of the intense infrared radiation emitted by fire. Techniques used for the design of coatings with high visible reflectivity in the 1 to 8 micron wavelength range important in fires are discussed.

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Appendix B

Material Suppliers

(3 pages)

1-GP-61Ma, 501-109

General Paint Marine 10-010 enamel (empress white)
General Paint
Vancouver, BC
(604) 253-3131

Matchless Super Marine gloss enamel exterior alkyd
Matchless Inc.
St. John's, NF
(709) 726-4432

1-GP-200, 503-305 & 501-302

2605 Non-slip deck coating, polyurethane (503-305)
2687 Non-slip deck coating, polyurethane (501-302)
Tibbetts Paints Ltd.
Trenton, NS
(902) 752-8301

Primers

For 1-GP-61 systems:

General Paint Industrial 63-048 interior/exterior alkyd anti-corrosive marine primer (1-GP-48M)

For 1-GP-200 systems:

353 Viny-lux primewash base and 354 reducer
Courtalds Coatings Inc.
Union, NJ
(908) 686-1300

Amercoat 68A zinc rich epoxy primer and cure solution
(1-GP-183M)
Amercoat Divison of Allcolour Paint Ltd.
Oakville, ON
(905) 847-1500

Resins

Aroplaz 2502-ML-60

Reichhold Inc.
North York, ON
(416) 742-0262

Desmophen A 160 (acrylic polyol)
Desmodur E-3265 (moisture-cure urethane prepolymer)

Bayer Inc.
Etobicoke, ON
(416) 248-3029

Pigment Suppliers

BASF
Etobicoke, ON
(416) 460-0664

Bayer Inc.
Etobicoke, ON
(416) 248-3029

Ciba-Geigy Canada Ltd.
Mississauga, ON
(905) 821-2343

Ferro Corp.
Cleveland, OH
(216) 641-8580

Harcros Pigments, Inc.
Etobicoke, ON
(416) 251-1161

Harshaw (Engelhard)
c/o Stochem Inc.
Brampton, ON
(905) 458-6888

Shepherd Color Co.
Cincinnati, OH
(513) 874-0714

Predispersed tinters were obtained from:

Hüls Canada Inc.
Brampton, ON
(905) 451-3810

Miscellaneous Materials

Bentone SD 3

Rheox Canada
North York, ON
(416) 223-9590

NeoCem 250
Dri Rx

OMG Group
c/o Tartan Color & Chemical Inc.
Mississauga, ON
(905) 821-2851

Nuxtra Cobalt 12%
Exkin #2

Hüls Canada Inc
Brampton, ON
(905) 451-3810

Talc - as supplied with 1-GP-200 coatings, or Nytal 300

St. Lawrence Chemical Inc.
Rexdale, ON
(416) 243-9615

Glass - as supplied with 1-GP-200 coatings

Polyethylene Fibre
Short Stuff 13038F

MiniFibers, Inc.
Johnson City, TN
(423) 282-4242

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Appendix C

Pigment Dispersion Formulations

(3 pages)

Alkyd Formulations

Alkyd Grind Vehicle	
Aroplaz 2502-ML-60	85.970
Xylene	14.030
	100.000

BASF L0086	
Alkyd Grind Vehicle	70.197
Paliogen L0086	19.533
Bentone SD 3	0.201
Xylene	10.068
	100.000

Bayer 130M	
Alkyd Grind Vehicle	65.763
Bayer 130M	33.898
Bentone SD 3	0.339
	100.000

Ciba 10405	
Alkyd Grind Vehicle	62.745
Irgacolor 10405	36.945
Bentone SD 3	0.310
	100.000

Ciba 10406	
Alkyd Grind Vehicle	59.750
Irgacolor 10406	39.962
Bentone SD 3	0.288
	100.000

Ferro V700	
Alkyd Grind Vehicle	57.389
Ferro V700	42.187
Bentone SD 3	0.424
	100.000

Ferro V11674	
Alkyd Grind Vehicle	61.643
Ferro V11674	37.981
Bentone SD 3	0.376
	100.000

Ferro V12600	
Alkyd Grind Vehicle	39.568
Ferro V12600	0.394
Bentone SD 3	100.000

Harshaw 9885	
Alkyd Grind Vehicle	63.904
Harshaw 9885	35.733
Bentone SD 3	0.363
	100.000

Shepherd 4	
Alkyd Grind Vehicle	56.120
Shepherd 4	43.445
Bentone SD 3	0.435
	100.000

Shepherd 179	
Alkyd Grind Vehicle	65.909
Shepherd 179	34.091
	100.000

Shepherd 195	
Alkyd Grind Vehicle	56.012
Shepherd 195	43.554
Bentone SD 3	0.435
	100.000

Shepherd 376	
Alkyd Grind Vehicle	57.757
Shepherd 376	41.824
Bentone SD 3	0.418
	100.000

Shepherd A8151	
Alkyd Grind Vehicle	64.317
Shepherd A8151	35.336
Bentone SD 3	0.347
	100.000

Acrylic Formulations

Acrylic Grind Vehicle	
Desmophen A 160	85.967
Xylene	14.033
	100.000

BASF L0084	
Acrylic Grind Vehicle	89.278
Paliogen L0084	10.599
Bentone SD 3	0.122
	100.000

Bayer 3910	
Acrylic Grind Vehicle	66.432
Bayer 3910	33.238
Bentone SD 3	0.329
	100.000

Ciba 3RLTN	
Acrylic Grind Vehicle	83.893
Irgazin 3RLTN	15.940
Bentone SD 3	0.168
	100.000

Ciba GLN	
Acrylic Grind Vehicle	82.304
Irgalite GLN	17.529
Bentone SD 3	0.167
	100.000

Ciba 10333	
Acrylic Grind Vehicle	62.465
Irgacolor 10333	37.172
Bentone SD 3	0.363
	100.000

Ciba 10342	
Acrylic Grind Vehicle	63.667
Irgacolor 10342	35.993
Bentone SD 3	0.340
	100.000

Harcros 6099	
Acrylic Grind Vehicle	68.360
Harcros 6099	31.332
Bentone SD 3	0.308
	100.000

Harshaw 9885	
Acrylic Grind Vehicle	56.385
Harshaw 9885	20.951
Xylene	22.664
	100.000

Shepherd 123	
Acrylic Grind Vehicle	47.530
Shepherd 123	28.961
Xylene	23.509
	100.000

Shepherd 179	
Acrylic Grind Vehicle	49.080
Shepherd 179	50.418
Bentone SD 3	0.502
	100.000

Shepherd 187	
Acrylic Grind Vehicle	61.445
Shepherd 187	38.178
Bentone SD 3	0.377
	100.000

Shepherd 376	
Acrylic Grind Vehicle	49.005
Shepherd 376	50.487
Bentone SD 3	0.508
	100.000

Ferro V700	
Acrylic Grind Vehicle	55.959
Ferro V700	43.605
Bentone SD 3	0.436
	100.000

Ferro V9238	
Acrylic Grind Vehicle	54.956
Ferro V9238	44.606
Bentone SD 3	0.437
	100.000
Ferro V11692	
Acrylic Grind Vehicle	43.983
Ferro V11692	55.477
Bentone SD 3	0.540
	100.000
Ferro V12600	
Acrylic Grind Vehicle	55.702
Ferro V12600	43.860
Bentone SD 3	0.439
	100.000

Appendix D

Pigment Particle Size Measurements

(11 pages)

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INTRODUCTION

Seven paint samples were received for the determination of particle size by laser diffraction. The samples were identified as follows:

Sample Reference	ORTECH Sample No.
Shepherd rutile yellow 195	96-J23-7222-06-B
Shepherd gray A8151	96-J23-7222-08-A
Harshaw 9885 high IR black	96-J23-7222-09-B
BASF Paliogen black L0084	96-J23-7222-11-B
Ferro V11674 green	96-J23-7222-21-A
Ferro V700 black	96-J23-7222-29
Kronos 2102 TiO_2	96-J23-7222-100-B

TEST METHOD

Malvern Mastersizer X

A representative portion of the sample was suspended in approximately 20 ml of xylene (Analar). The sample was immersed in a low-power ultrasonic bath (80 Watts) for 1 minute to aid in disrupting any loosely bound aggregates and analyzed using the Malgvern Mastersizer X, which uses a laser diffraction method of particle detection.

RESULTS

The particle size results are calculated based on volume percent. The particle size distribution outputs are appended. If you have any questions please do not hesitate to call us.

B. Smith
Project Technician
Pharmaceutical & Consumer Products

J. McNeill, M.Sc., C.Chem.
Manager
Pharmaceutical & Consumer Products

APPENDIX: Particle Size Outputs

(7 Pages)

ORTECH

Software Version 1.2

Tue, Dec 17, 1996 1:44PM

ORTECH SAMPLE ID 96-J23-7222-08-B :Run Number 1

SAMPLE 96-J23-7222-08-B
DISPERSED IN XYLENE, ANALAR, LOT 108775/1999
1 MINUTE SONICATION 80 WATTS
OPERATOR BRAD SMITH, REPORT 96-B21-U004955-1-115
FILE: 6BJ7222, Record: 1 Source: Laser Diffraction Analyzer
Measured on: Tue, Dec 17, 1996 1:43PM Last saved on: Tue, Dec 17, 1996 1:44PM

Presentation: 2OHD
Very Polydisperse model

VOLUME RESULTS

Focus = 100 mm.

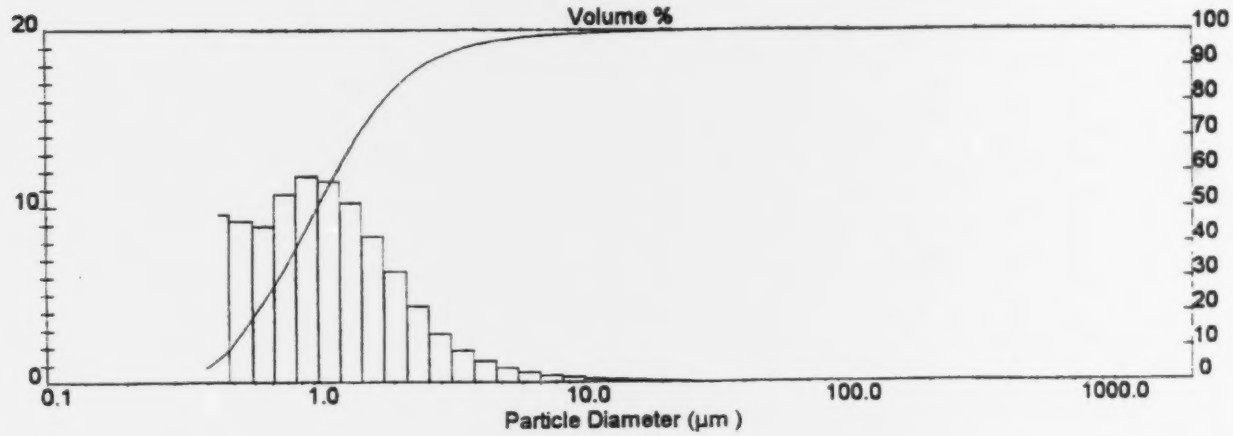
Residual = 0.463 %
MEDIAN, d(0.5) = 1.04 µm
MEAN, D(4, 3) = 1.48 µm
MODE = 0.97 µm

Concentration = 0.001 %
d (0.1) = 0.49 µm
Span = (d0.9 - d0.1)/d0.5 = 2.01

Obscuration = 22.95 %
d (0.9) = 2.57 µm

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	9.59	0.48	9.59
0.48	9.21	0.59	18.80
0.59	8.91	0.71	27.71
0.71	10.70	0.86	38.42
0.86	11.75	1.04	50.17
1.04	11.49	1.26	61.67
1.26	10.25	1.52	71.92
1.52	8.36	1.84	80.28
1.84	6.34	2.23	86.61
2.23	4.35	2.70	90.96
2.70	2.81	3.27	93.78
3.27	1.87	3.95	95.65
3.95	1.25	4.79	96.90
4.79	0.86	5.79	97.76
5.79	0.60	7.01	98.37
7.01	0.43	8.48	98.80

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	0.31	10.27	99.11
10.27	0.24	12.43	99.35
12.43	0.18	15.05	99.53
15.05	0.15	18.21	99.68
18.21	0.11	22.04	99.79
22.04	0.09	26.68	99.88
26.68	0.06	32.29	99.94
32.29	0.04	39.08	99.98
39.08	0.02	47.30	99.99
47.30	0.01	57.25	100.00
57.25	0.00	69.30	100.00
69.30	0.00	83.87	100.00
83.87	0.00	101.52	100.00
101.52	0.00	122.87	100.00
122.87	0.00	148.72	100.00
148.72	0.00	180.00	100.00



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Malvern, U.K.

MasterSizer X Ver. 1.2
Serial No. 6286

17 Dec 96 13:11

ORTECH

Software Version 1 2

Tue, Dec 17, 1996 2.10PM

ORTECH SAMPLE ID 96-J23-7222-8-A :**Run Number** 1

SAMPLE 96-J23-7222-8-A
DISPERSED IN XYLENE, ANALAR, LOT 108775/1999
1 MINUTE SONICATION 80 WATTS
OPERATOR BRAD SMITH, REPORT 96-B21-U004955-1-115
FILE. 8AF2154 , Record: 1
Measured on: Tue, Dec 17, 1996 2.09PM Last saved on: Tue, Dec 17, 1996 2.10PM

Source: Laser Diffraction Analyzer

Presentation: 2OHD
Very Polydisperse model

VOLUME RESULTS

Focus = 100 mm

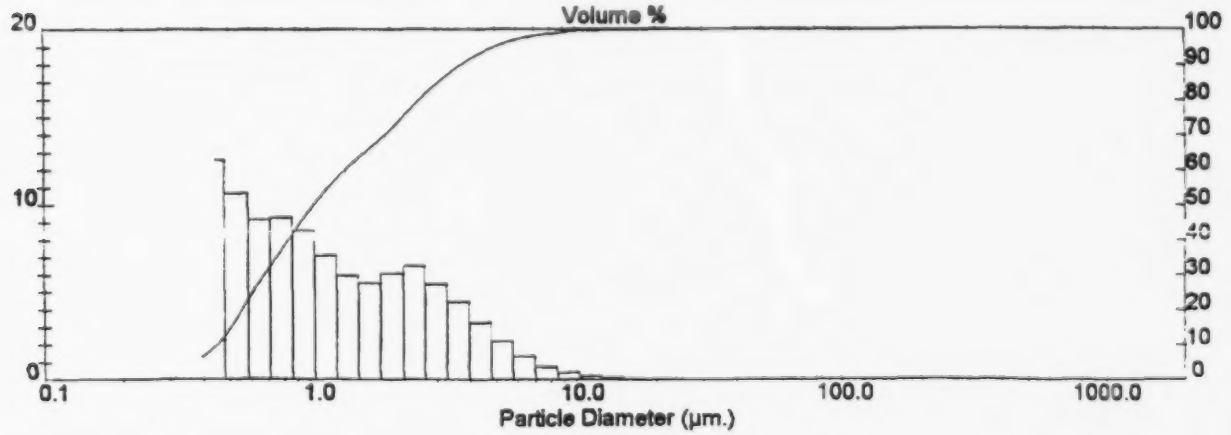
Residual = 0.341 %
MEDIAN, d(0.5) = 1.03 µm
MEAN, D(4, 3) = 1.70 µm
MODE = 0.56 µm

Concentration = 0.001 %
d (0.1) = 0.45 µm
Span = (d0.9 - d0.1)/d0.5 = 3.15

Obscuration = 30.72 %
d (0 9) = 3.71 µm

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	12.62	0.48	12.62
0.48	10 63	0.59	23.25
0.59	9.17	0 71	32.42
0.71	9.26	0 86	41 68
0.86	8.52	1.04	50 21
1.04	7.15	1 26	57 36
1.26	5.96	1 52	63.32
1.52	5.53	1 84	68.85
1.84	6.10	2.23	74.95
2.23	6.50	2.70	81.46
2.70	5 47	3.27	86.92
3.27	4 45	3.95	91.37
3.95	3.28	4.79	94.65
4 79	2.22	5.79	96.87
5.79	1.35	7.01	98.22
7.01	0.78	8.48	99.00

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	0.44	10 27	99 44
10.27	0.24	12.43	99 68
12.43	0.14	15.05	99 82
15.05	0.08	18.21	99 90
18.21	0.05	22.04	99 95
22.04	0.03	26 68	99.97
26.68	0.02	32.29	99 99
32.29	0.01	39 08	100 00
39.08	0.00	47 30	100 00
47 30	0.00	57 25	100.00
57 25	0.00	69 30	100 00
69.30	0 00	83 87	100.00
83 87	0 00	101 52	100 00
101 52	0.00	122 87	100 00
122.87	0.00	148 72	100 00
148.72	0.00	180 00	100 00



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Malvern, U.K.

MasterSizer X Ver. 1.2
Serial No. 6286

17 Dec 96 14 10

ORTECH

Software Version 1 2

Tue, Dec 17, 1996 1 38PM

ORTECH SAMPLE ID 96-J23-7222-09-B :Run Number 1

SAMPLE 96-J23-7222-09-B
DISPERSED IN XYLENE, ANALAR, LOT 108775/1999
1 MINUTE SONICATION 80 WATTS
OPERATOR BRAD SMITH, REPORT 96-B21-U004955-1-115
FILE: 98J7222 , Record: 1
Measured on: Tue, Dec 17, 1996 1.23PM Last saved on: Tue, Dec 17, 1996 1:38PM

Source. Laser Diffraction Analyzer

Presentation: 2OHD
Very Polydisperse model

VOLUME RESULTS

Focus = 100 mm

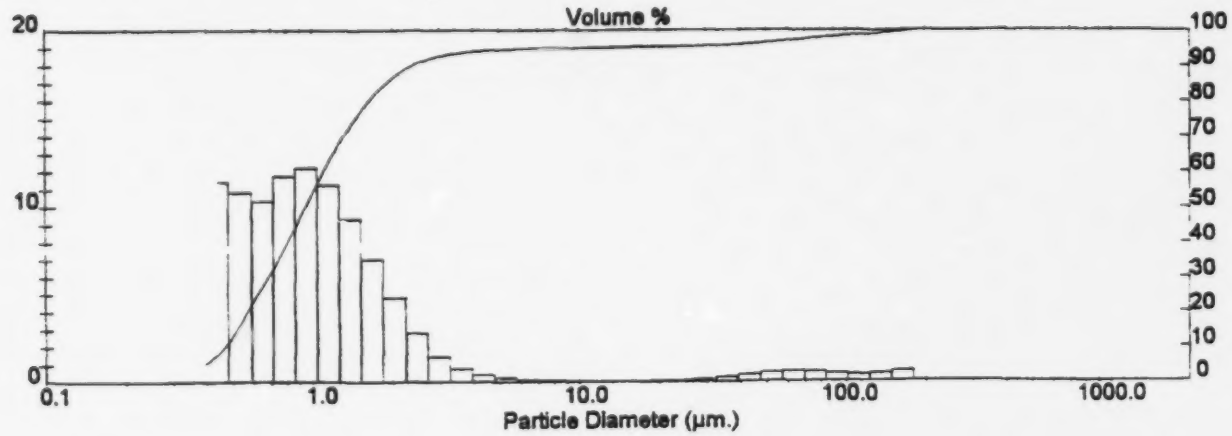
Residual = 0.348 %
MEDIAN, d(0.5) = 0.94 µm
MEAN, D[4, 3] = 5.02 µm
MODE = 0.92 µm

Concentration = 0.001 %
d (0.1) = 0.46 µm
Span = (d0.9 - d0.1)/d0.5 = 2.01

Obscuration = 29 16 %
d (0 9) = 2.35 µm

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	11 45	0.48	11 45
0.48	10.83	0.59	22.28
0.59	10.35	0 71	32.63
0.71	11 77	0.86	44 40
0.86	12.23	1.04	56.63
1.04	11 24	1.26	67 87
1.26	9.34	1.52	77.21
1.52	7 04	1 84	84 26
1.84	4 81	2.23	89.08
2.23	2.80	2.70	91 86
2.70	1.45	3.27	93.32
3.27	0.79	3.95	94 11
3.95	0 44	4.79	94 54
4 79	0.25	5.79	94 79
5.79	0.15	7 01	94.94
7.01	0.10	8.48	95.04

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8 48	0 07	10 27	95 11
10.27	0.06	12.43	95 17
12.43	0.06	15 05	95 23
15.05	0.06	18 21	95 29
18 21	0 08	22.04	95 36
22.04	0.11	26 68	95 47
26.68	0.17	32 29	95 64
32.29	0.28	39 08	95 92
39.08	0.42	47 30	96 34
47 30	0.55	57 25	96 89
57.25	0.60	69 30	97 49
69.30	0.58	83.87	98 07
83.87	0.47	101 52	98 53
101 52	0.40	122.87	98 94
122.87	0.47	148 72	99 40
148.72	0.60	180.00	100 00



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MasterSizer X Ver. 1.2
Serial No. 6286

17 Dec 96 13 3:

ORTECH

Software Version 1 2

Tue, Dec 17, 1996 1 52PM

ORTECH SAMPLE ID 96-J23-7222-21-A :Run Number 1

SAMPLE 96-J23-7222-21-A
DISPERSED IN XYLENE, ANALAR, LOT 108775/1999
1 MINUTE SONICATION 80 WATTS
OPERATOR BRAD SMITH, REPORT 96-821-U004955-1-115
FILE. 21AJ7222, Record 1
Measured on: Tue, Dec 17, 1996 1 51PM Last saved on Tue, Dec 17, 1996 1 52PM

Source Laser Diffraction Analyzer

Presentation: 2OHD
Very Polydisperse model

VOLUME RESULTS

Focus = 100 mm

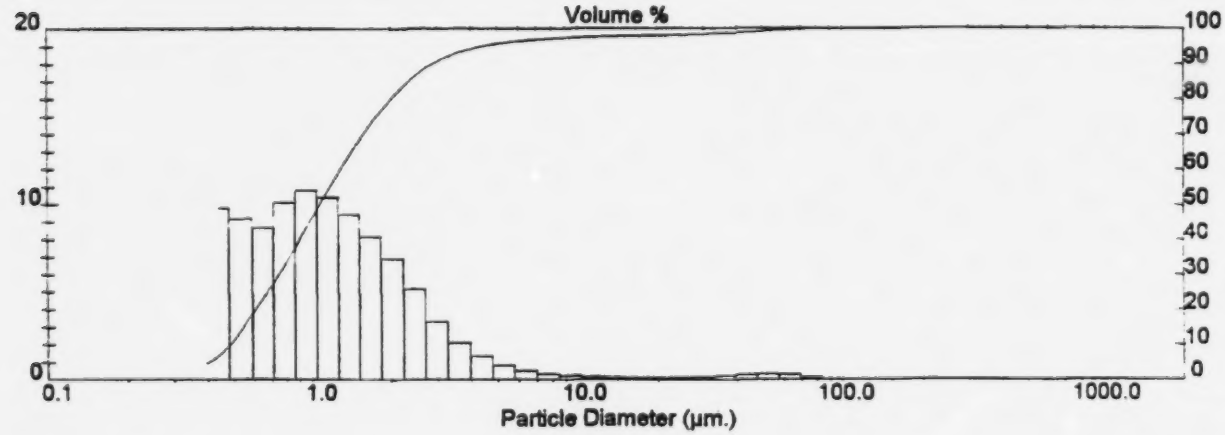
Residual = 0.398 %
MEDIAN, d(0.5) = 1.07 µm
MEAN, D(4, 3) = 2.32 µm
MODE = 0.95 µm

Concentration = 0.001 %
d (0.1) = 0.48 µm
Span = (d0 9 - d0.1)/d0.5 = 2.25

Obscuration = 25.31 %
d (0.9) = 2.88 µm

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	9.83	0.48	9.83
0.48	9.17	0.59	18 99
0.59	8.66	0.71	27 65
0.71	10.10	0.86	37 76
0.86	10.82	1.04	48.58
1.04	10.43	1.26	59.00
1.26	9.42	1.52	68.42
1.52	8.17	1.84	76.60
1.84	6.92	2.23	83.52
2.23	5.19	2.70	88.71
2.70	3.33	3.27	92.04
3.27	2.14	3.95	94 18
3.95	1 35	4.79	95 53
4 79	0.86	5.79	96 39
5.79	0.55	7.01	96.93
7.01	0.36	8.48	97 29

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	0.25	10 27	97 55
10.27	0.19	12.43	97 74
12.43	0.16	15 05	97 90
15.05	0.14	18 21	98.04
18.21	0.14	22.04	98 18
22.04	0.15	26 68	98 33
26.68	0.19	32.29	98 52
32.29	0.25	39 08	98 76
39 08	0 32	47 30	99 08
47 30	0.37	57 25	99 45
57 25	0.33	69 30	99 78
69.30	0.18	83 87	99 96
83.87	0.04	101 52	100 00
101 52	0 00	122.87	100.00
122.87	0.00	148.72	100.00
148.72	0.00	180 00	100.00



Malvern Instruments Ltd.
alvern, U K.

MasterSizer X Ver. 1 2
Serial No. 6286

17 Dec 96 13 52

ORTECH

Software Version 1 2

Tue, Dec 17, 1996 2:02PM

ORTECH SAMPLE ID 96-J23-7222-11-B :Run Number 1

SAMPLE 96-J23-7222-11-B
DISPERSED IN XYLENE, ANALAR, LOT 108775/1999
1 MINUTE SONICATION 80 WATTS
OPERATOR BRAD SMITH, REPORT 96-B21-U004955-1-115
FILE: 11AJ7222, Record: 1
Measured on: Tue, Dec 17, 1996 2:00PM Last saved on: Tue, Dec 17, 1996 2:02PM

Source: Laser Diffraction Analyzer

Presentation: 2OHD
Very Polydisperse model

VOLUME RESULTS

Focus = 100 mm.

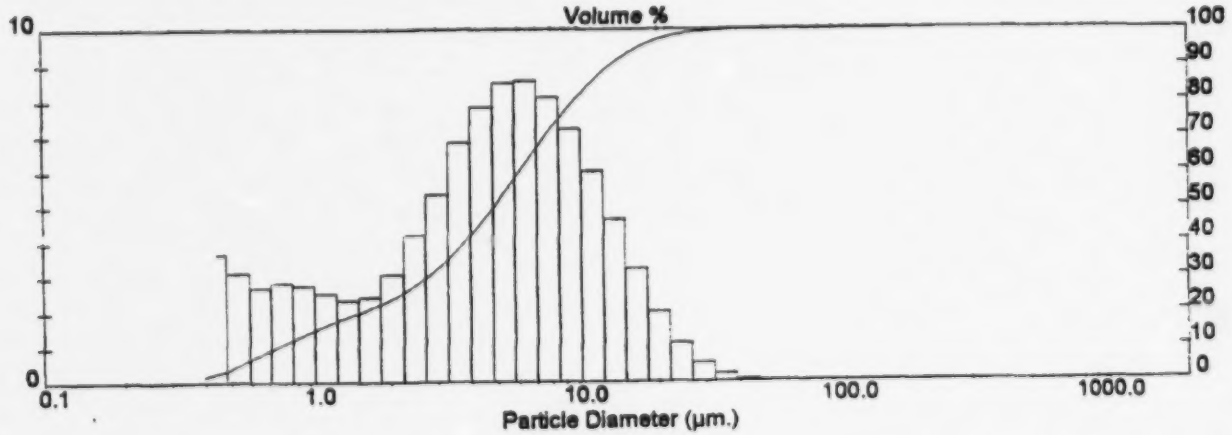
Residual = 0.707 %
MEDIAN, d(0.5) = 4.82 µm
MEAN, D(4, 3) = 6.21 µm
MODE = 5.62 µm

Concentration = 0.002 %
d (0.1) = 0.74 µm
Span = (d0.9 - d0.1)/d0.5 = 2.62

Obscuration = 24.02 %
d (0.9) = 13.36 µm

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	3.66	0.48	3.66
0.48	3.12	0.59	6.77
0.59	2.71	0.71	9.49
0.71	2.84	0.86	12.33
0.86	2.77	1.04	15.10
1.04	2.54	1.26	17.63
1.26	2.36	1.52	19.99
1.52	2.45	1.84	22.44
1.84	3.08	2.23	25.52
2.23	4.20	2.70	29.73
2.70	5.34	3.27	35.07
3.27	6.82	3.95	41.89
3.95	7.83	4.79	49.72
4.79	8.50	5.79	58.23
5.79	8.56	7.01	66.79
7.01	8.09	8.48	74.88

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	7.21	10.27	82.08
10.27	6.01	12.43	88.09
12.43	4.64	15.05	92.73
15.05	3.24	18.21	95.97
18.21	2.02	22.04	97.98
22.04	1.13	26.68	99.11
26.68	0.56	32.29	99.67
32.29	0.24	39.08	99.91
39.08	0.08	47.30	99.98
47.30	0.02	57.25	100.00
57.25	0.00	69.30	100.00
69.30	0.00	83.87	100.00
83.87	0.00	101.52	100.00
101.52	0.00	122.87	100.00
122.87	0.00	148.72	100.00
148.72	0.00	180.00	100.00



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Malvern, U.K.

MasterSizer X Ver. 1.2
Serial No. 6286

17 Dec 96 14:02

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2-12-17

ORTECH

Software Version 1 2

Tue, Dec 17, 1996 2:18PM

ORTECH SAMPLE ID 96-J23-7222-29 **:Run Number 1**

SAMPLE 96-J23-7222-29
DISPERSED IN XYLENE, ANALAR, LOT 108775/1999
1 MINUTE SONICATION 80 WATTS
OPERATOR BRAD SMITH, REPORT 96-B21-U004955-1-115
FILE: 29J7222 . Record: 1
Measured on: Tue, Dec 17, 1996 2:17PM Last saved on: Tue, Dec 17, 1996 2:18PM

Source: Laser Diffraction Analyzer

Presentation: 2OHD
Very Polydisperse model

VOLUME RESULTS

Focus = 100 mm

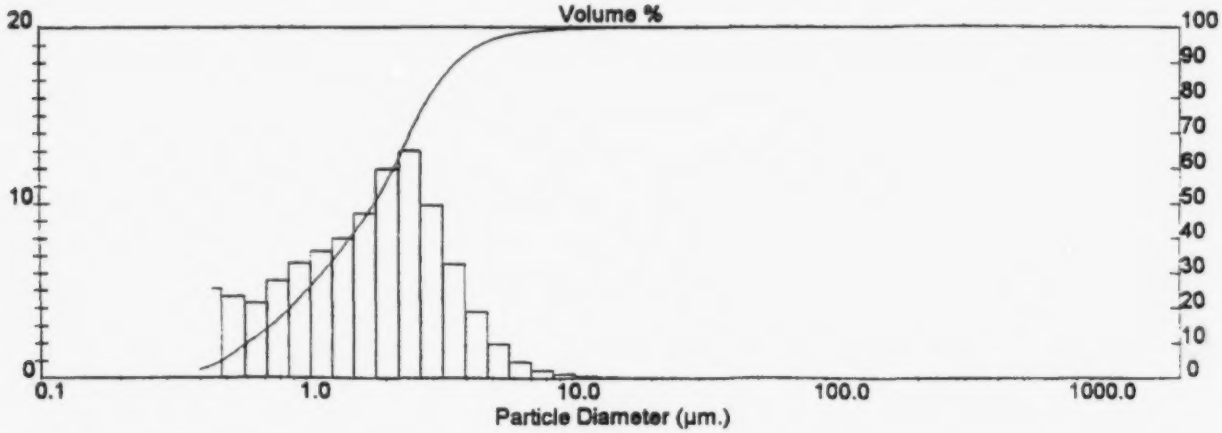
Residual = 0.242 %
MEDIAN, d(0.5) = 1.81 µm
MEAN, D[4, 3] = 2.07 µm
MODE = 2.37 µm

Concentration = 0.001 %
d (0.1) = 0.60 µm
Span = (d0.9 - d0.1)/d0.5 = 1.70

Obscuration = 29 34 %
d (0.9) = 3.67 µm

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	5.12	0.48	5.12
0.48	4 64	0.59	9.76
0.59	4 30	0.71	14 06
0.71	5.56	0.86	19.61
0.86	6.59	1.04	26.20
1.04	7 26	1.26	33 46
1.26	8.00	1 52	41 45
1.52	9 40	1.84	50 86
1.84	11.92	2.23	62.78
2.23	12.96	2.70	75.74
2.70	9 89	3.27	85 63
3.27	6.50	3 95	92.13
3 95	3.79	4 79	95 92
4 79	1 98	5.79	97 90
5.79	0.97	7.01	98.87
7.01	0.49	8.48	99 35

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	0.26	10.27	99 61
10.27	0.14	12.43	99.75
12.43	0.09	15 05	99 84
15.05	0.06	18 21	99 90
18.21	0.04	22.04	99 94
22.04	0.03	26 68	99 97
26.68	0.02	32.29	99 98
32.29	0.01	39 08	99 99
39.08	0.00	47 30	100 00
47.30	0.00	57 25	100 00
57.25	0.00	69 30	100.00
69.30	0.00	83 87	100 00
83.87	0.00	101 52	100.00
101.52	0.00	122.87	100 00
122.87	0.00	148.72	100 00
148.72	0.00	180.00	100 00



Malvern Instruments Ltd.
alvern, U.K.

MasterSizer X Ver. 1.2
Serial No. 6286

17 Dec 96 14 18

ORTECH

Software Version 1 2

Wed, Dec 18, 1996 7 53AM

ORTECH SAMPLE ID 96-J23-7222-100-B :Run Number 1

SAMPLE 96-J23-7222-100-B
DISPERSED IN XYLENE, ANALAR, LOT 108775/1999
1 MINUTE SONICATION 80 WATTS
OPERATOR BRAD SMITH, REPORT 96-B21-U004955-1-115
FILE: 10087222, Record: 2
Measured on: Tue, Dec 17, 1996 2:25PM Last saved on: Wed, Dec 18, 1996 7 53AM

Source Laser Diffraction Analyzer

Presentation: 2OHD
Very Polydisperse model

VOLUME RESULTS

Focus = 100 mm.

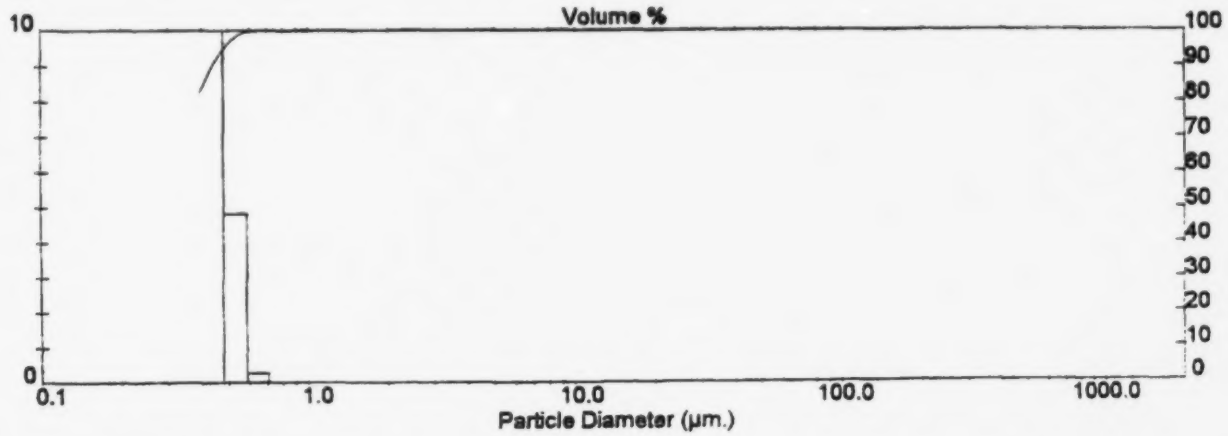
Residual = 1.565 %
MEDIAN, d(0.5) = 0.29 µm
MEAN, D(4, 3) = 0.32 µm
MODE = 0.00 µm

Concentration = 0.001 %
d (0.1) = 0 21 µm
Span = (d0.9 - d0.1)/d0.5 = 0.78

Obscuration = 24 03 %
d (0.9) = 0.44 µm

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
0.20	94.87	0.48	94 87
0.48	4 83	0.59	99.70
0.59	0.30	0.71	100.00
0.71	0.00	0.86	100.00
0.86	0.00	1.04	100.00
1.04	0.00	1.26	100.00
1.26	0.00	1.52	100.00
1.52	0.00	1.84	100.00
1.84	0.00	2.23	100.00
2.23	0.00	2.70	100.00
2.70	0.00	3.27	100 00
3.27	0.00	3.95	100 00
3.95	0.00	4.79	100.00
4.79	0.00	5.79	100.00
5.79	0.00	7.01	100.00
7.01	0.00	8.48	100.00

Size (Lo) µm	Result In %	Size (Hi) µm	Result Below %
8.48	0.00	10 27	100.00
10.27	0.00	12.43	100.00
12.43	0 00	15 05	100 00
15.05	0.00	18 21	100.00
18.21	0 00	22.04	100.00
22.04	0.00	26.68	100 00
26.68	0.00	32.29	100 00
32.29	0 00	39 08	100.00
39.08	0 00	47 30	100 00
47 30	0.00	57.25	100 00
57 25	0.00	69 30	100 00
69 30	0.00	83 87	100 00
83 87	0.00	101 52	100 00
101 52	0.00	122.87	100 00
122.87	0.00	148.72	100.00
148.72	0.00	180 00	100 00



Malvern Instruments Ltd.
Malvern, U.K.

MasterSizer X Ver. 1 2
Serial No. 6286

18 Dec 96 07 53

Appendix E

Infrared Spectrometry Measurements

(16 pages)

P516888.PDF [Page: 66 of 183]

1. INTRODUCTION

Five grey paint samples, each on a metal substrate, were submitted for infrared analysis by reflectance.

One sample was labeled as General Marine Standard 1-GP-61, the remaining four samples had been given the following ORTECH Sample Numbers: 96J23-7222-55, 96J23-7222-57, 96J23-7222-68 and 96J23-7222-87

2. EXPERIMENTAL AND RESULTS

All raw data are referenced in Lab Book No. J21-7520.

Infrared analysis was carried out using a Bio-Rad FTS 175 Fourier transform infrared (FTIR) spectrometer (ORTECH MII #A11694, calibration valid until 96/12/26) equipped with an Analect FX-530 reflectance accessory operating in the specular reflectance mode.

Copies of the infrared spectra are included in Appendix A.

The infrared spectra obtained are shown in both the full wavelength range (4000 cm^{-1} to 800 cm^{-1}) and expanded in the area of most analytical interest (2000 cm^{-1} to 800 cm^{-1}) for clarity.

Spectra #1 to #5 shows the reflectance spectra from samples General Marine Standard, 96J23-7222-55, 96J23-7222-57, 96J23-7222-68 and 96J23-7222-87, respectively.

Spectrum #6 shows the above five spectra overlapped for comparison.

S. V. Hannah
Project Technologist
Polymer Chemistry

Hillar Auksi, Ph.D.
Manager
Polymer Chemistry

P516888.PDF [Page: 68 of 183]

APPENDIX A

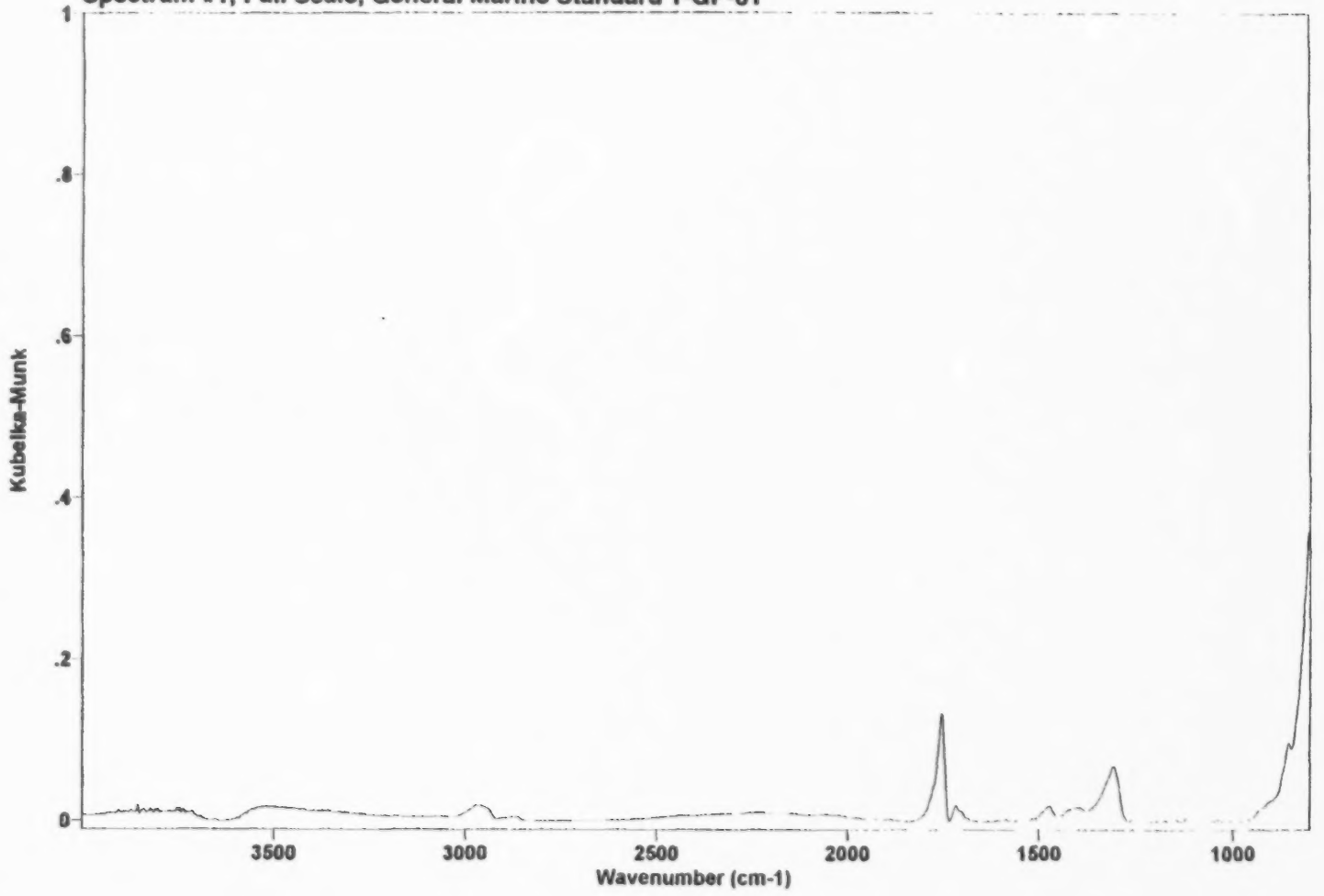
Infrared Spectra

(12 pages)

P516888.PDF [Page: 69 of 183]

ORTECH

Spectrum #1, Full Scale, General Marine Standard 1-GP-61



File # 1 : 9622406A

Number of Scans: 64

Comment: GENERAL MARINE STANDARD 1-GP-61

View Mode: Paged

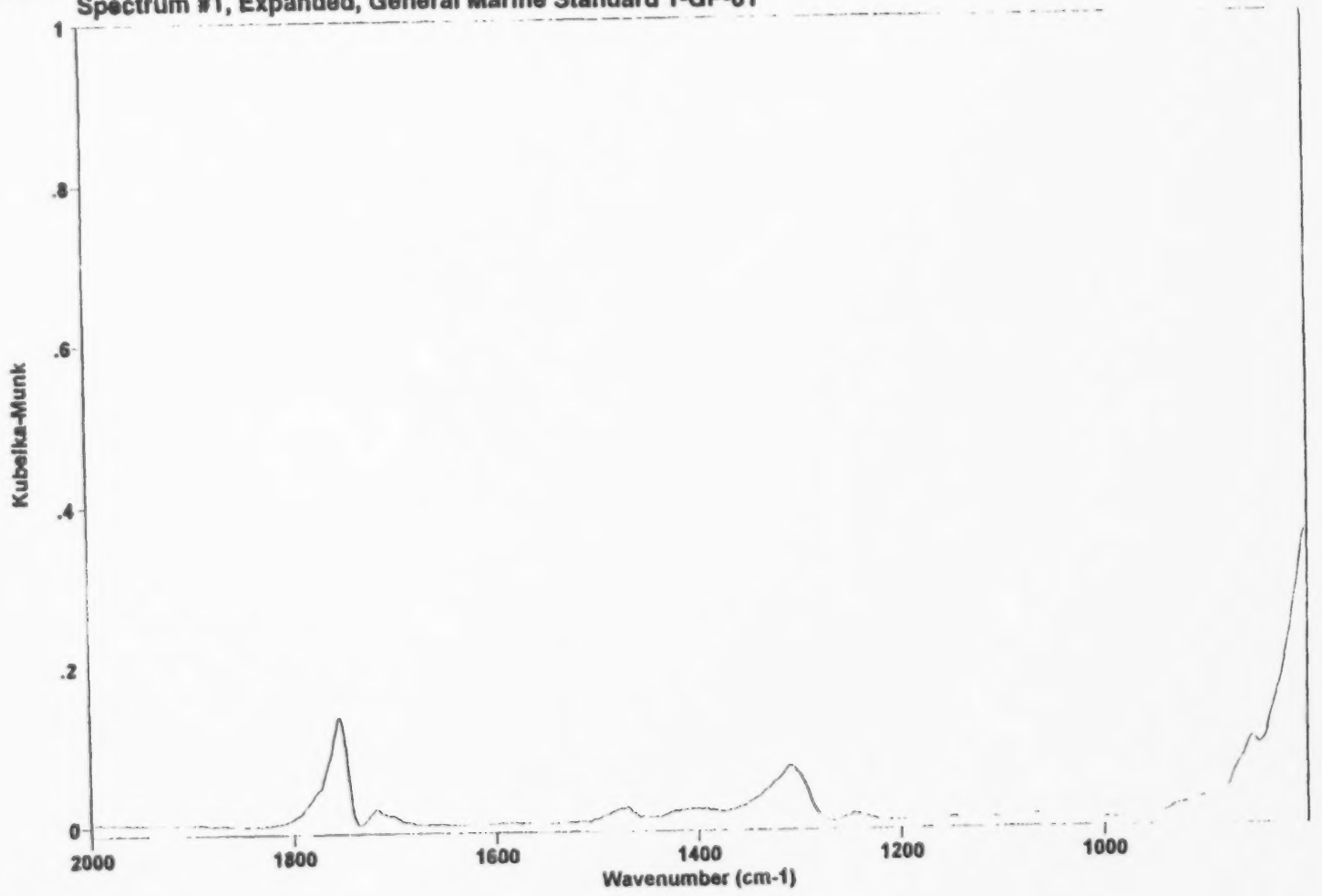
12/17/96 12:08 PM Res=4cm-1

Operator: J Chauvin

P516888.PDF [Page: 70 of 183]

ORTECH

Spectrum #1, Expanded, General Marine Standard 1-GP-61



File # 1 : 9622406A

Number of Scans: 64

Comment: GENERAL MARINE STANDARD 1-GP-61

View Mode: Paged

12/17/96 12:08 PM Res=4cm-1

Operator: J. Hanlon

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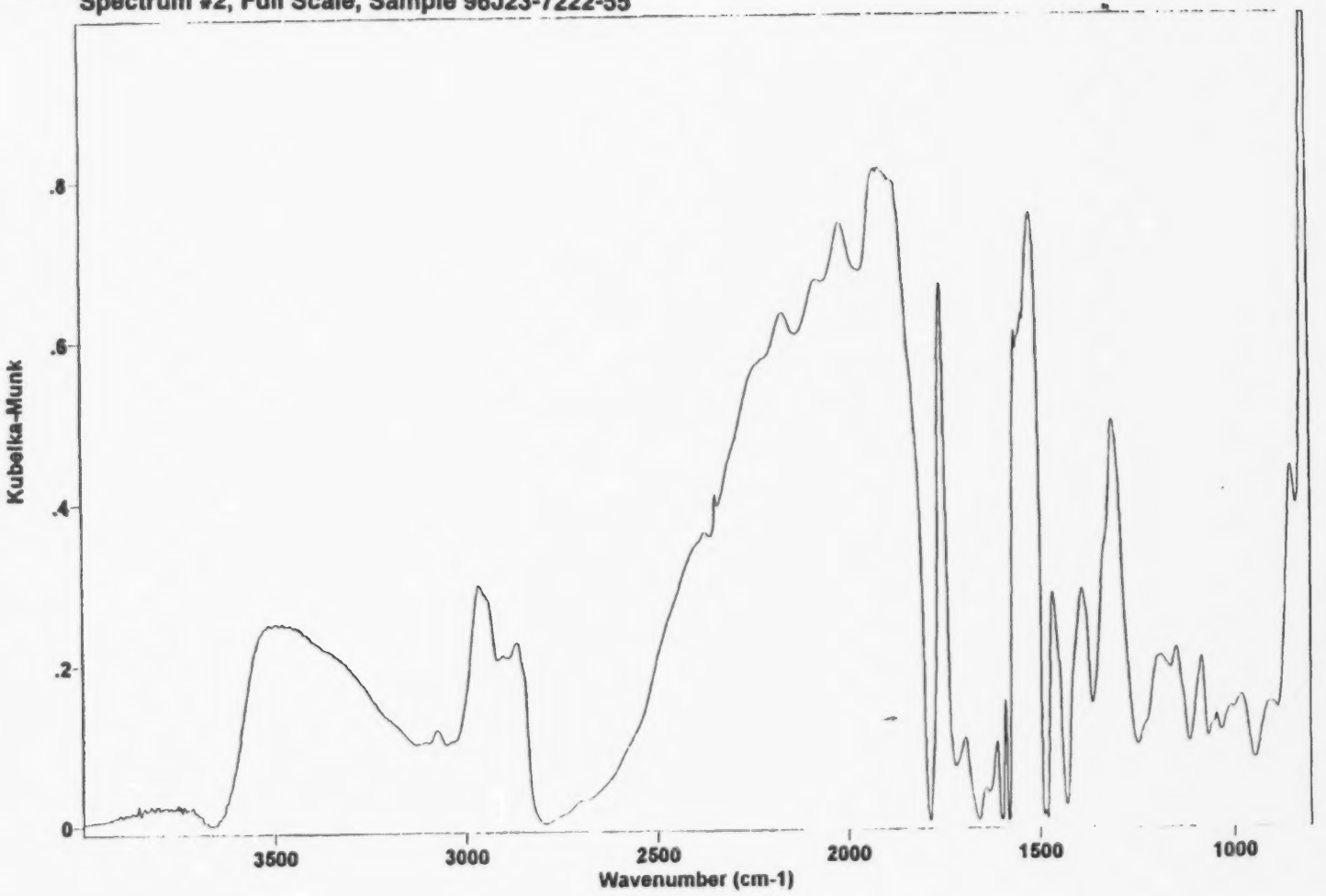
ORTECH

Spectrum #2, Full Scale, Sample 96J23-7222-55



File # 1 : 9622406B

Number of Scans: 64

Comment: 96J23-7222-55 1-GP-61

View Mode: Peaks

12/17/96 12:14 PM Res=4cm-1

Operator: Adamiak

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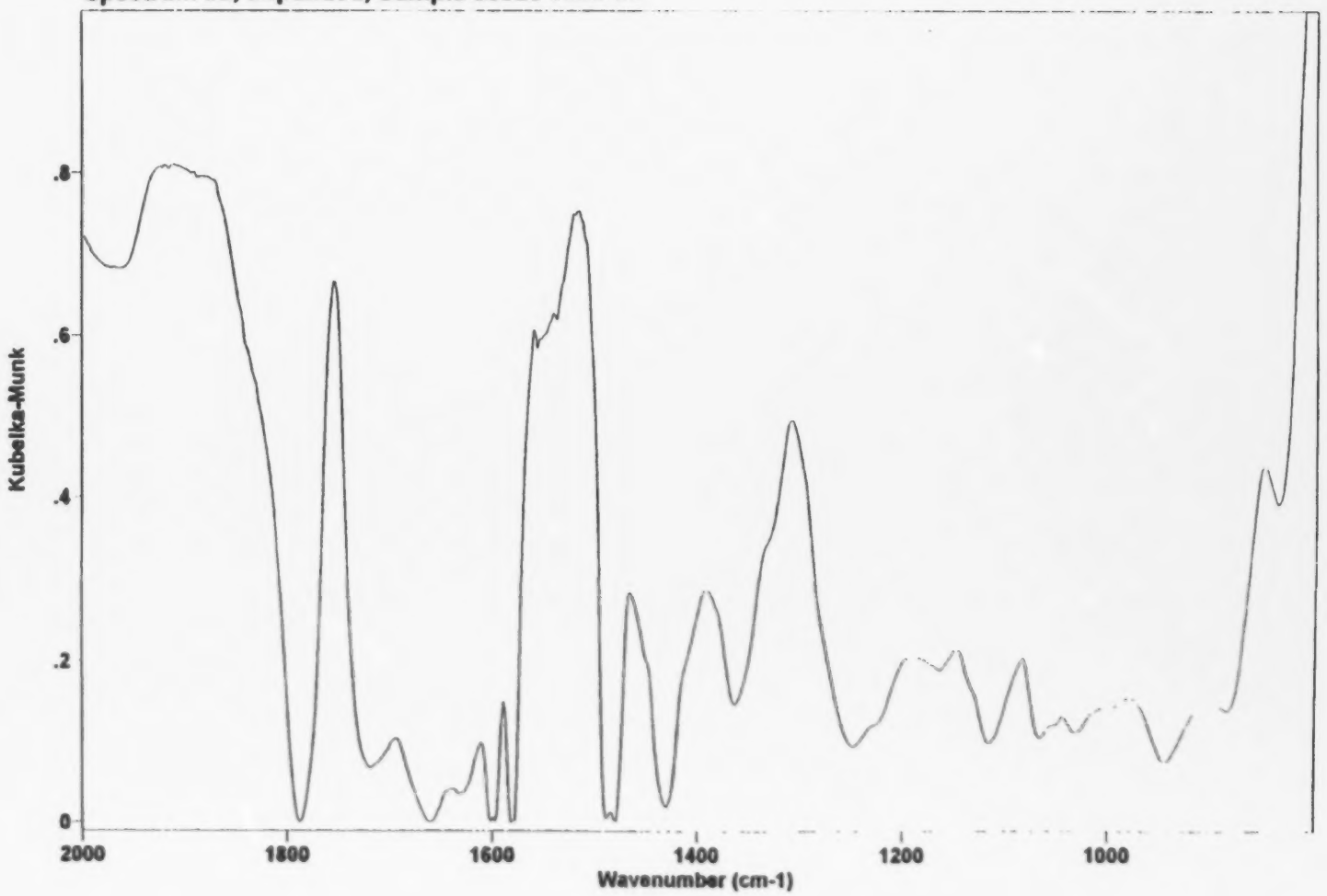
ORTECH

Spectrum #2, Expanded, Sample 96J23-7222-55



File # 1 : 9622406B

Number of Scans: 64

Comment: 96J23-7222-55 1-GP-61

View Mode: Peaks

12/17/96 12:14 PM Res=4cm-1

Operator:

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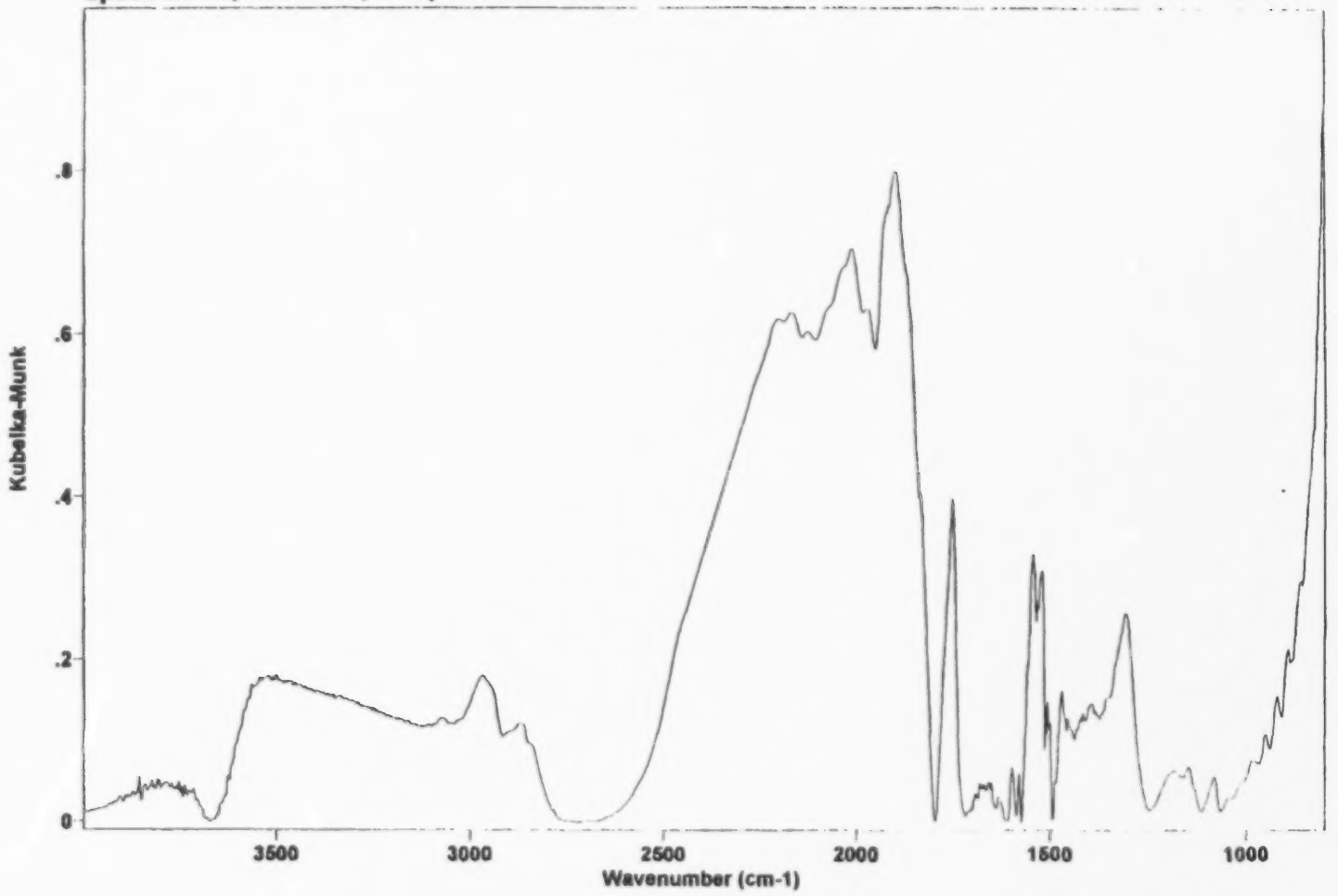
ORTECH

Spectrum #3, Full Scale, Sample 96J23-7222-57



File # 2 : 9622406C

Number of Scans: 64

Comment: 96J23-7222-57 1-GP-61

View Mode: Paged

12/17/96 12:17 PM Res=4cm-1

Operator: JMunk

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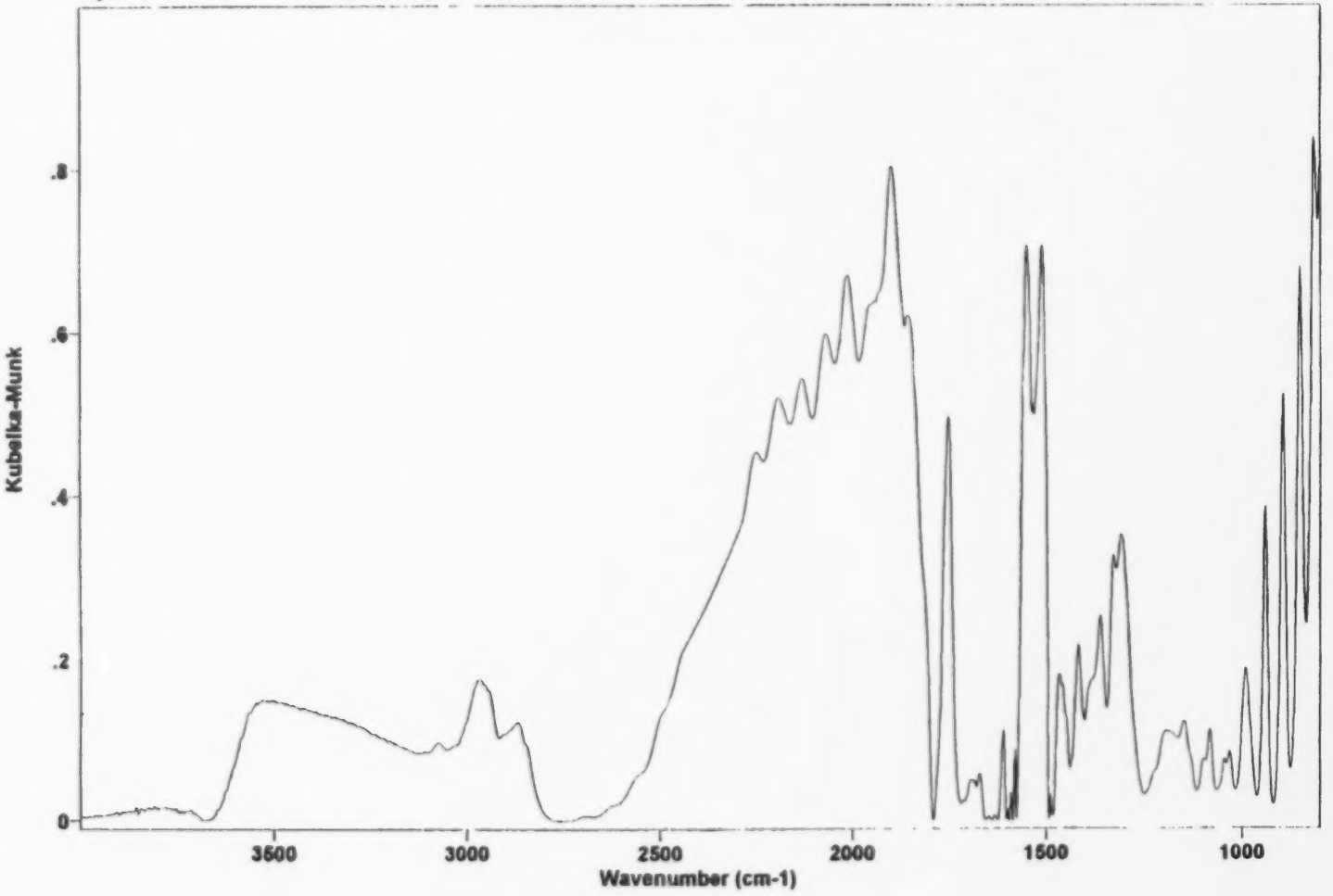
ORTECH

Spectrum #4, Full Scale, Sample 96J23-7222-68



File # 2 : 9622406D

Number of Scans: 64

Comment: 96J23-7222-68 1-GP-61

View Mode: Paged

12/17/96 12:19 PM Res=4cm-1

Operator: AKannah

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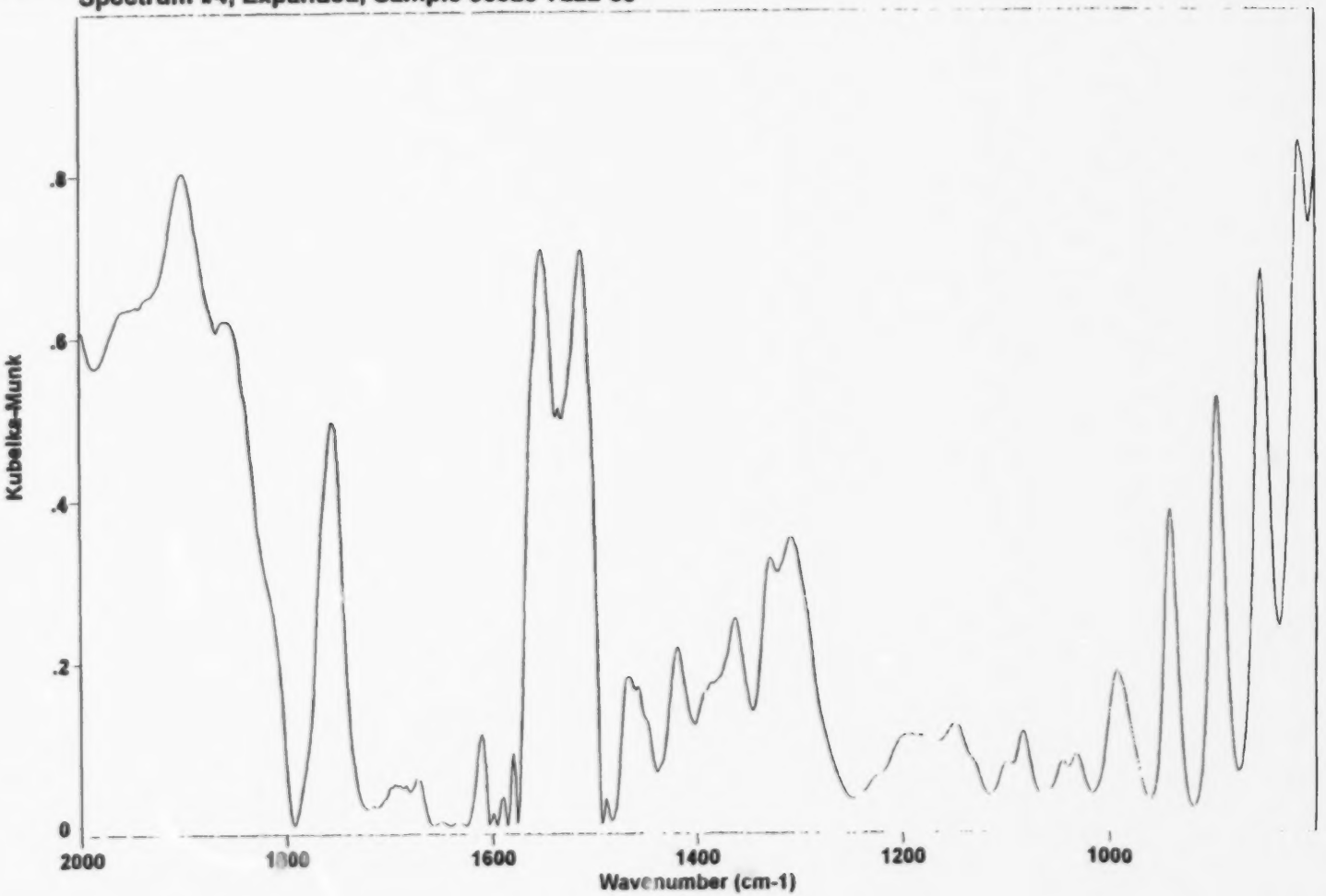
ORTECH

Spectrum #4, Expanded, Sample 96J23-7222-68



File # 2 : 9622406D

Number of Scans: 64

Comment: 96J23-7222-68 1-GP-61

View Mode: Paged

12/17/96 12:19 PM Res=4cm-1

Operator: AKumar

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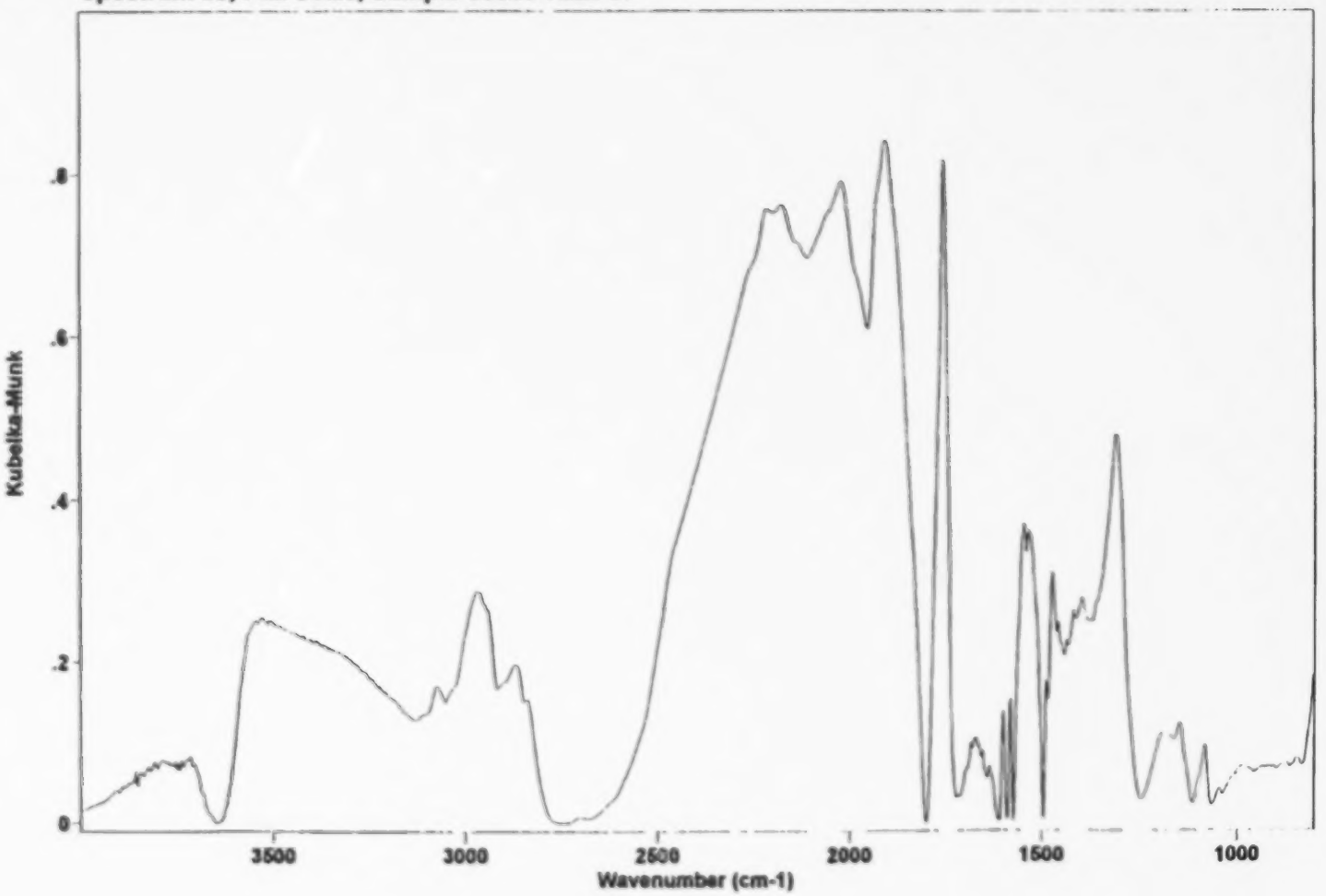
ORTECH

Spectrum #5, Full Scale, Sample 96J23-7222-87



File # 1 : 9622406E

Number of Scans: 64

Comment: 96J23-7222-87 1-GP-61

View Mode: Overlay

12/17/96 12:26 PM Res=4cm-1

Operator: AMurrah

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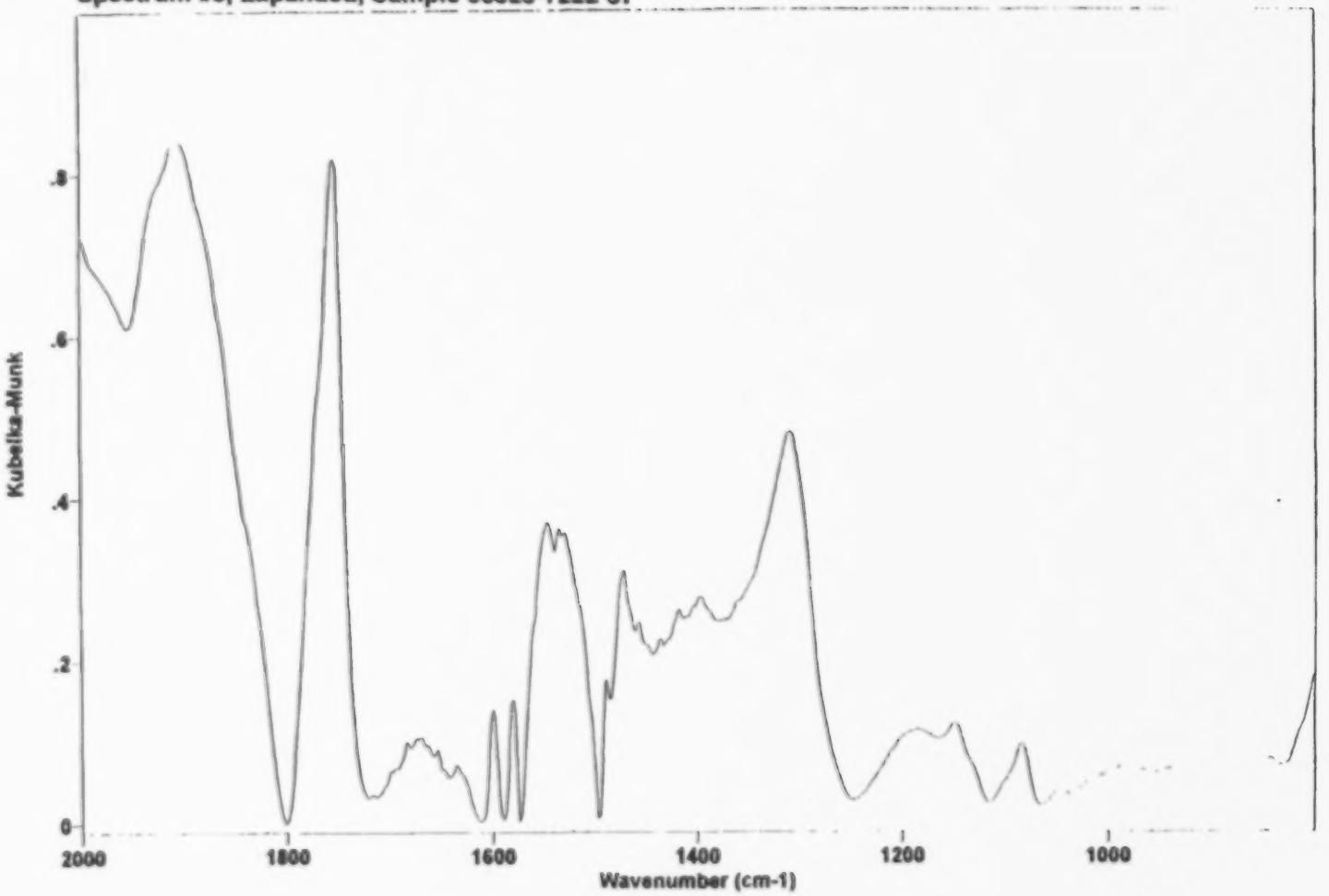
ORTECH

Spectrum #5, Expanded, Sample 96J23-7222-87



File # 1 : 9622406E

Number of Scans: 64

Comment: 96J23-7222-87 1-GP-61

View Mode: Overlay

12/17/96 12:26 PM Res=4cm-1

Operator:

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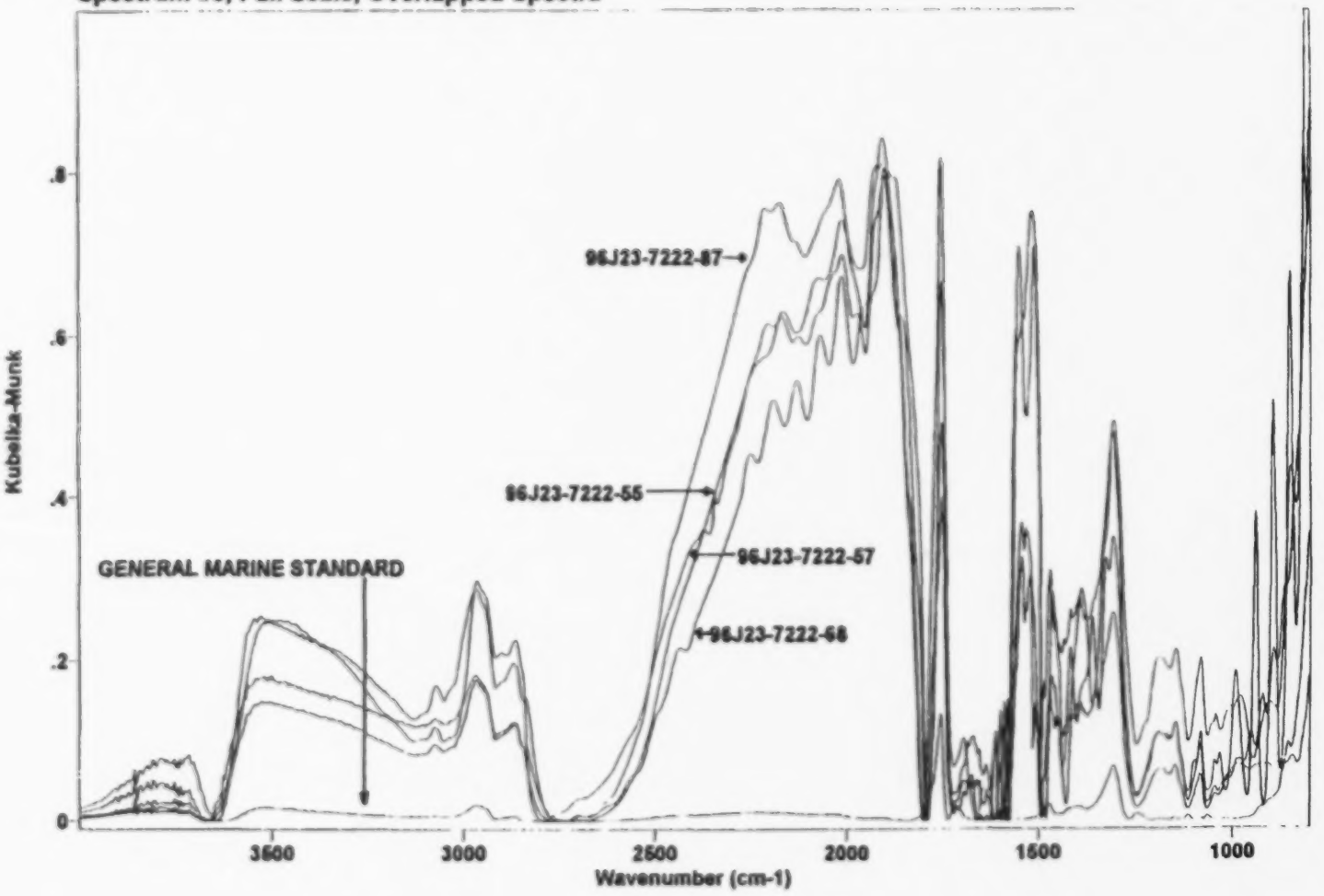
ORTECH

Spectrum #6, Full Scale, Overlapped Spectra



File # 5 : 9622406E

Number of Scans: 64

Comment: 96J23-7222-87 1-GP-61

View Mode: Overlay

12/17/96 12:26 PM Res=4cm-1

Operator: A Kumar

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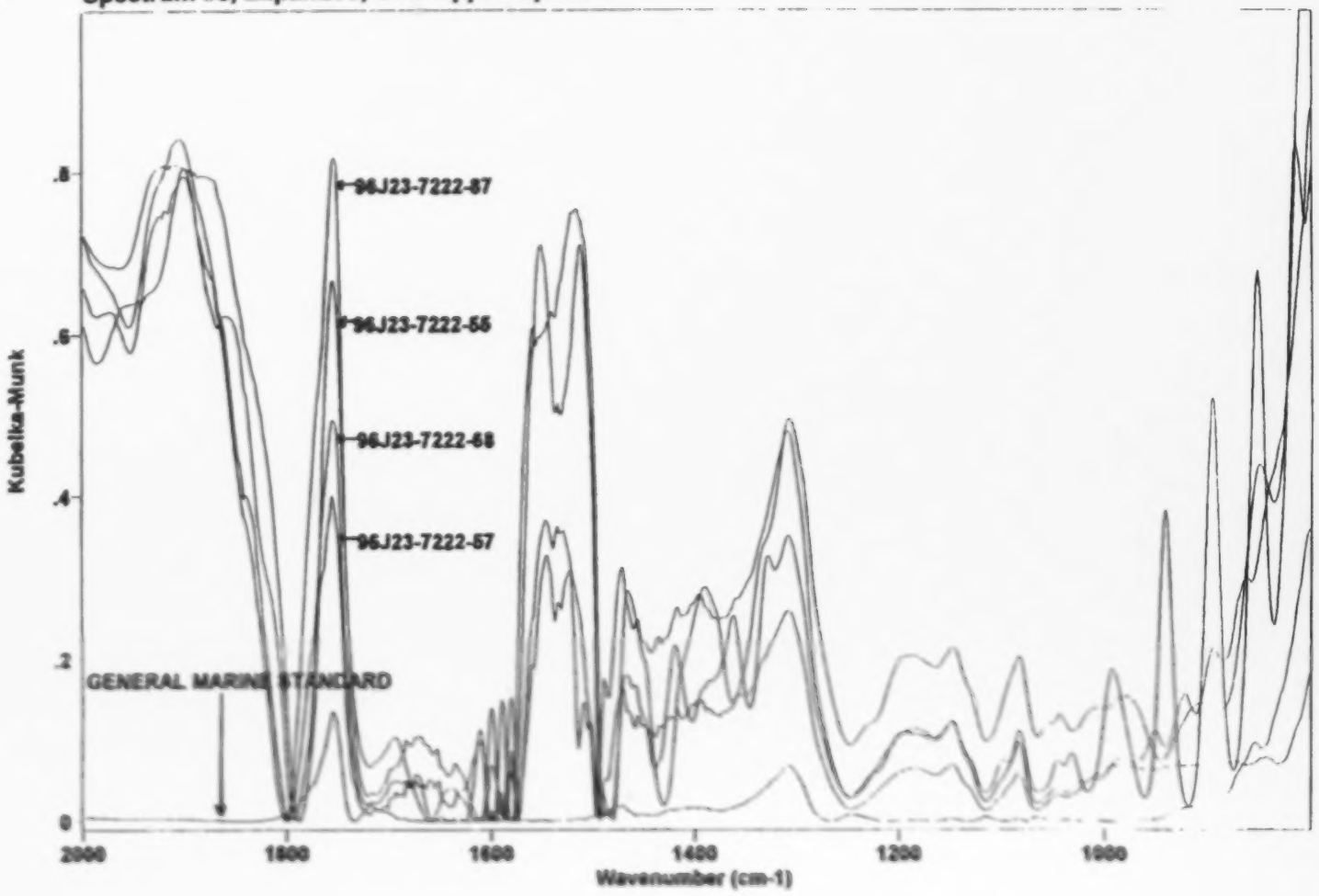
ORTECH

Spectrum #6, Expanded, Overlapped Spectra



File # 5 : 9622406E

Number of Scans: 64

Comment: 96J23-7222-67 1-GP-61

View Mode: Overlay

12/17/96 12:26 PM Res=4cm-1

Operator:

Appendix F

Thermography Measurements

(6 pages)

REGISTRATION

ISO 9002-1994, registered by QMI, Registration #001109.

INTRODUCTION

At the request of Mr. David Hacker, a thermographic scan of three sets of panels was conducted. The panels were placed in the solar environmental chamber until stabilization of the panel temperatures was recorded. Stabilization was measured by means of thermocouples placed in the centre (back) of each panel.

TEST PROCEDURE

In order to determine the approximate heat reflective effect of each coating, two foot square steel panels were coated with the standard coating and the experimental coating having the best infrared-reflectance curve for each colour. The panels were heated with a solar lamp. The temperature of the reverse side of each panel was measured with a thermocouple. In order to determine the emissivity of the coatings, the front panel temperature was assumed to be 5°C higher than the reverse side panel temperatures for each of the panels.

The experimental conditions were as follows:

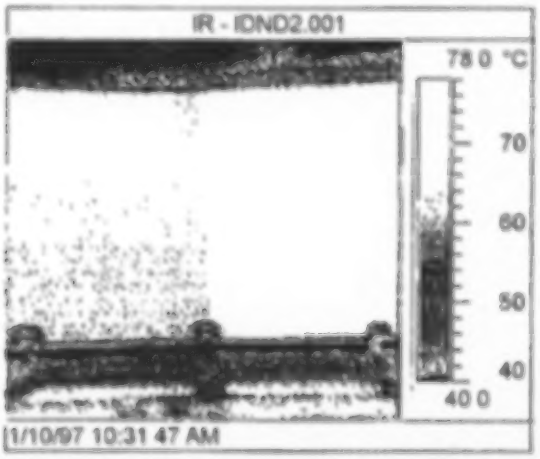
Solar energy was provided by a Vortek™ 150 kW Solar Simulator lamp (MII No. A06264). The distance from the lamp to the panels was approximately 29 ft. The light intensity at the panel surface was 970 to 980 W/m^2 as measured using a pyranometer (MII No. B00034). Control and test panels were mounted side by side, 30° from the vertical, so that the incident light was normal to the surface. A type K thermocouple was soldered to the centre of the back of each panel. Temperatures were monitored with a digital meter (MII No. A05281). Thermography was carried out once the panels had reached an equilibrium temperature. This took about 15 minutes for the 1-GP-61 panels, and 20 to 30 minutes for the two 1-GP-200 panels.

An Agema 470 Thermovision infrared camera (MII A10168) was used to conduct the scan. Thermal images of the panels were recorded onto diskette for analysis. The thermographic images (thermograms) display apparent surface temperatures. Warmer surfaces are indicated by light colours (orange, red, white) and cooler surfaces are indicated by dark colours (violet, blue, black). A colour temperature scale is provided beside each thermal image as a reference. The accuracy of the thermographic camera, based upon manufacturer's specifications, is 2°C or 2%, whichever is less.

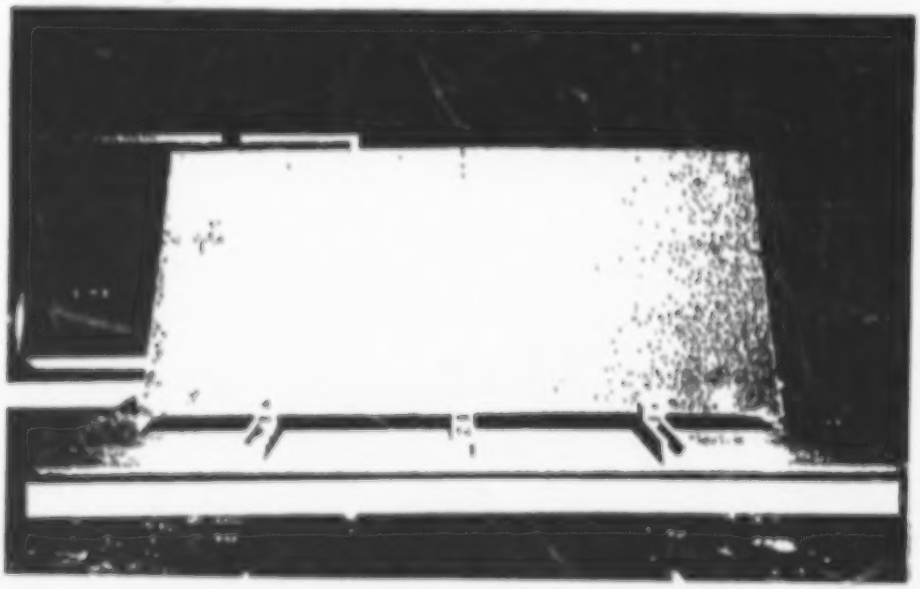
REPORT

The thermograms included in this report have been analyzed based upon the average emissivity value for the set of coatings.

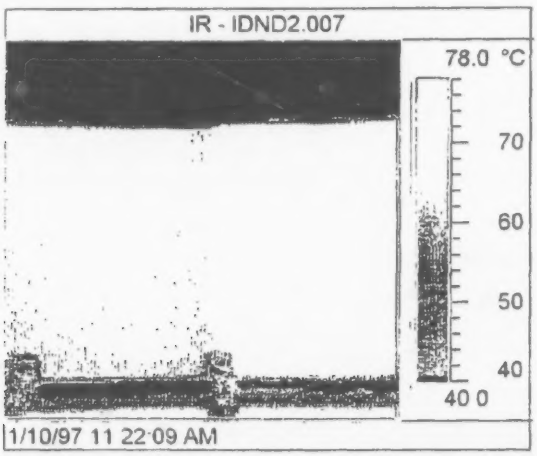
1-GP-200, 503-305 Dark Green Panels	
7222-122	Tibbets Standard
Reverse side panel temperature = 60 9°C	Reverse side panel temperature = 69 3°C
Assumed face panel temperature = 65.9°C	Assumed face panel temperature = 74.3°C
Calculated emissivity = 0 89	Calculated emissivity = 0 92



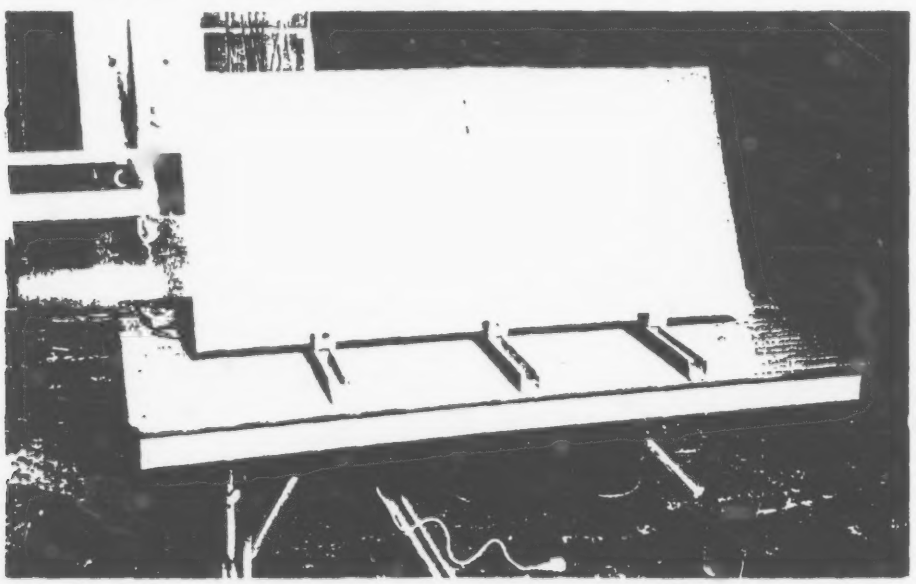
SCANNER DATA	
Level	471
Sens	6
Aperture	0
Filter	NOF
Lens	20
IMAGE OBJ. PAR	
Emissivity	0.91
Amb temp.	29 2 °C
Atm. temp	25 7 °C
Object dist	3.0 m
Transmission	0.97



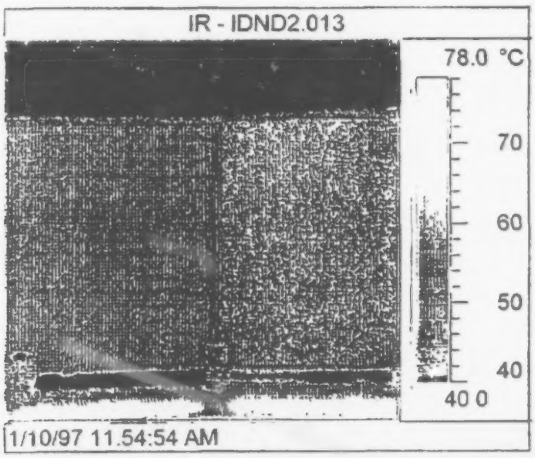
1-GP-200, 501-302 Dark Grey Panels	
7222-123	Tibbets Standard
Reverse side panel temperature = 62 6°C	Reverse side panel temperature = 70 1°C
Assumed face panel temperature = 67.6°C	Assumed face panel temperature = 75.1°C
Calculated emissivity = 0.87	Calculated emissivity = 0.92



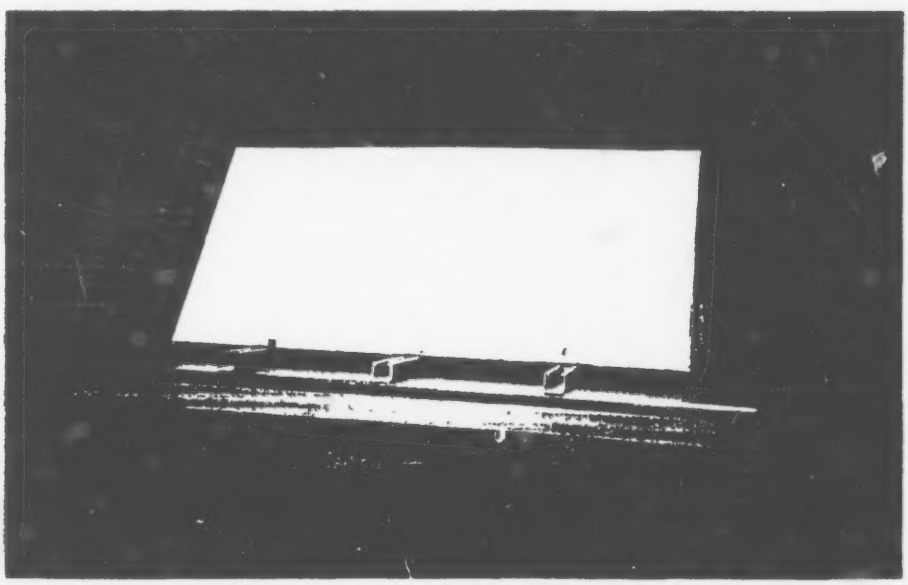
SCANNER DATA	
Level	471
Sens	6
Aperture	0
Filter	NOF
Lens	20
IMAGE OBJ. PAR.	
Emissivity	0.90
Amb. temp.	30 2 °C
Atm. temp.	27 0 °C
Object dist.	3.0 m
Transmission	0.97



1-GP-61, 501-109 Light Grey Panels	
7222-57	General Paint Standard
Reverse side panel temperature = 44.0°C	Reverse side panel temperature = 52 8°C
Assumed face panel temperature = 49.0°C	Assumed face panel temperature = 57.8°C
Calculated emissivity = 0.95	Calculated emissivity = 1 00



SCANNER DATA	
Level	913
Sens	7
Aperture	0
Filter	NOF
Lens	20
IMAGE OBJ PAR.	
Emissivity	0 97
Amb temp	30.5 °C
Atm. temp	28 6 °C
Object dist.	3 0 m
Transmission	0.97



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CONCLUSION

For each set of panels examined, the standard coatings exhibited higher emissivity values, i.e. the formulated coatings were more reflective. Please note that the calculated emissivity values are relative values for each set. The values cannot be compared between sets.

Pamela Miki Shinkoda, P.Eng.
Acting Section Manager - Products
Building Performance Technology

David W. Bailey, P.Eng.
Area Manager
Building Performance

Appendix G

Reflectance and Colour Data for Individual Pigments

(48 pages)

Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 14:57 16:Dec:9

RSEX/UVL OFF/UVF OUT/LA

STANDARD NAME: Shep BL#376 Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	9.49
a*	1.09
b*	0.36

W/L	Standard	W/L	Standard
400	1.05	760	2.19
410	1.03	770	2.29
420	1.05	780	2.44
430	1.05	790	2.60
440	1.06	800	2.82
450	1.04	810	3.07
460	1.03	820	3.34
470	1.04	830	3.61
480	1.01	840	3.90
490	1.01	850	4.24
500	1.02	860	4.58
510	1.02	870	4.95
520	1.02	880	5.33
530	1.02	890	5.72
540	1.03	900	6.08
550	1.03	910	6.47
560	1.06	920	6.87
570	1.06	930	7.25
580	1.09	940	7.64
590	1.10	950	8.02
600	1.10	960	8.38
610	1.12	970	8.77
620	1.13	980	9.11
630	1.20	990	9.44
640	1.19	1000	9.77
650	1.27	1010	10.09
660	1.28	1020	10.42
670	1.39	1030	10.72
680	1.34	1040	11.03
690	1.48	1050	11.28
700	1.58	1060	11.52
710	1.67	1070	11.71
720	1.71	1080	11.83
730	1.71	1090	11.97
740	1.85	1100	12.31
750	2.06		

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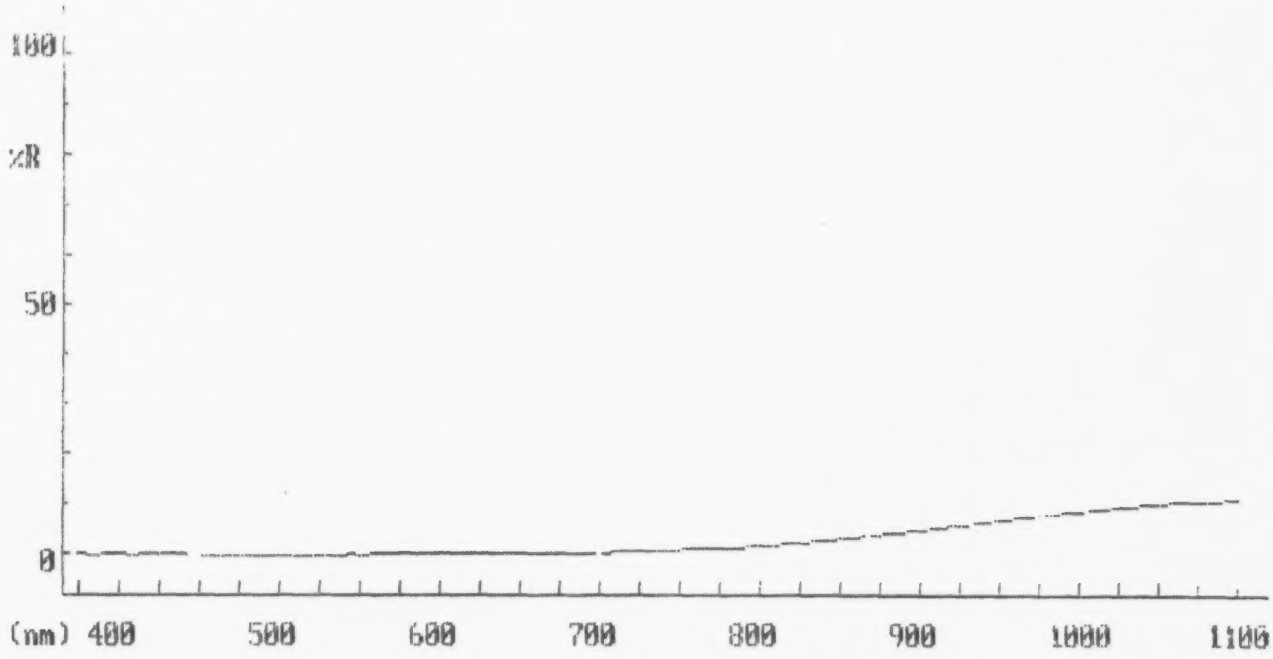
Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Shep BL#376 Mass



Report # 97-123-3204-1 (Solar Heat Refle .093)
UltraScan SpecWare, version 1.09 15:21 16:Dec:9
RSEX/UVL OFF/UVF OUT/LA

STANDARD NAME: Bayer Red oxide 130 m Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	27.96
a*	35.70
b*	31.78

W/L	Standard	W/L	Standard
400	1.02	760	34.48
410	1.05	770	33.58
420	1.05	780	32.47
430	1.06	790	31.24
440	1.05	800	30.05
450	1.06	810	28.99
460	1.05	820	28.05
470	1.06	830	27.32
480	1.08	840	26.77
490	1.10	850	26.44
500	1.14	860	26.31
510	1.17	870	26.38
520	1.24	880	26.64
530	1.30	890	27.12
540	1.47	900	27.81
550	1.82	910	28.72
560	2.61	920	29.82
570	4.29	930	31.13
580	7.13	940	32.66
590	10.80	950	34.38
600	14.31	960	36.25
610	16.96	970	38.22
620	18.80	980	40.23
630	19.94	990	42.18
640	20.82	1000	44.03
650	21.71	1010	45.68
660	22.74	1020	47.10
670	24.11	1030	48.30
680	25.58	1040	49.30
690	27.32	1050	50.16
700	29.17	1060	50.79
710	31.09	1070	51.11
720	32.82	1080	51.23
730	34.10	1090	51.42
740	34.77	1100	52.07
750	34.95		

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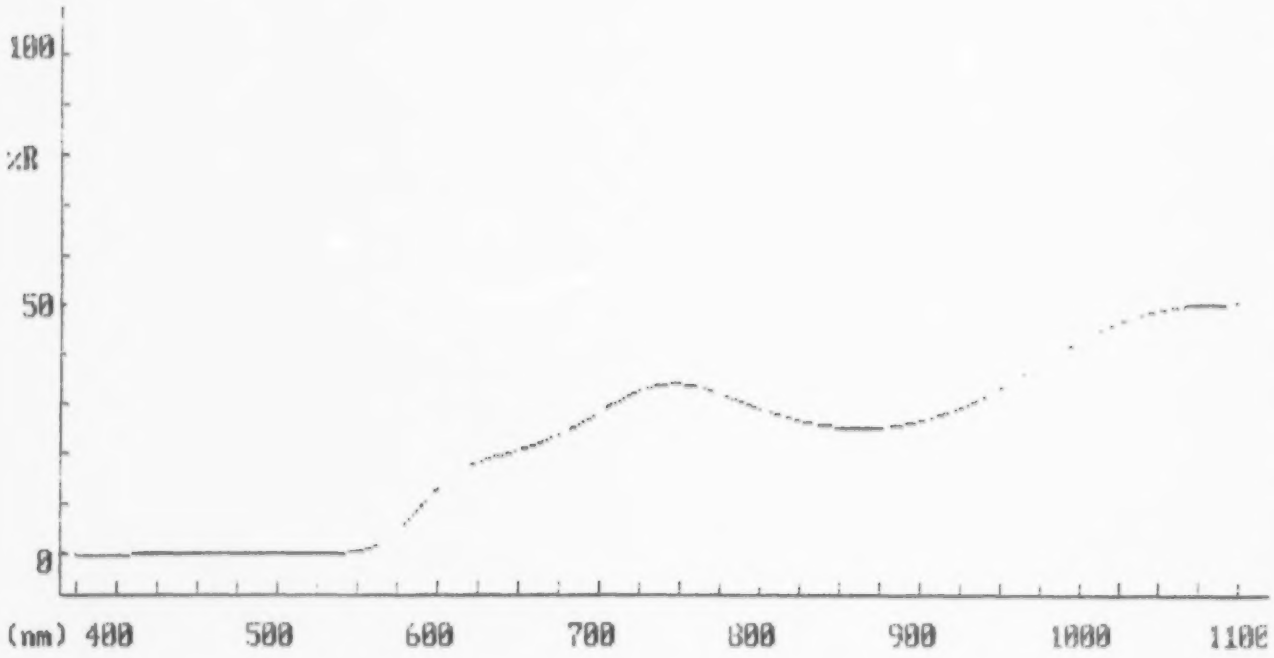
Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Bayer Red oxide



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Ciba 10333 Black #15AC
SAMPLE NAME:
10 DEGREE D65

	STD
L*	7.79
a*	0.91
b*	0.76

W/L	Standard	W/L	Standard
400	0.75	760	2.11
410	0.79	770	2.24
420	0.78	780	2.47
430	0.81	790	2.77
440	0.80	800	3.10
450	0.81	810	3.44
460	0.83	820	3.80
470	0.82	830	4.18
480	0.82	840	4.57
490	0.81	850	4.95
500	0.83	860	5.35
510	0.83	870	5.76
520	0.84	880	6.16
530	0.85	890	6.54
540	0.84	900	6.94
550	0.85	910	7.32
560	0.84	920	7.67
570	0.84	930	8.02
580	0.87	940	8.36
590	0.88	950	8.67
600	0.89	960	8.97
610	0.92	970	9.25
620	0.96	980	9.52
630	0.96	990	9.76
640	1.01	1000	10.01
650	1.05	1010	10.23
660	1.09	1020	10.43
670	1.15	1030	10.63
680	1.22	1040	10.81
690	1.25	1050	10.99
700	1.30	1060	11.15
710	1.40	1070	11.24
720	1.55	1080	11.27
730	1.64	1090	11.31
740	1.75	1100	11.54
750	1.99		

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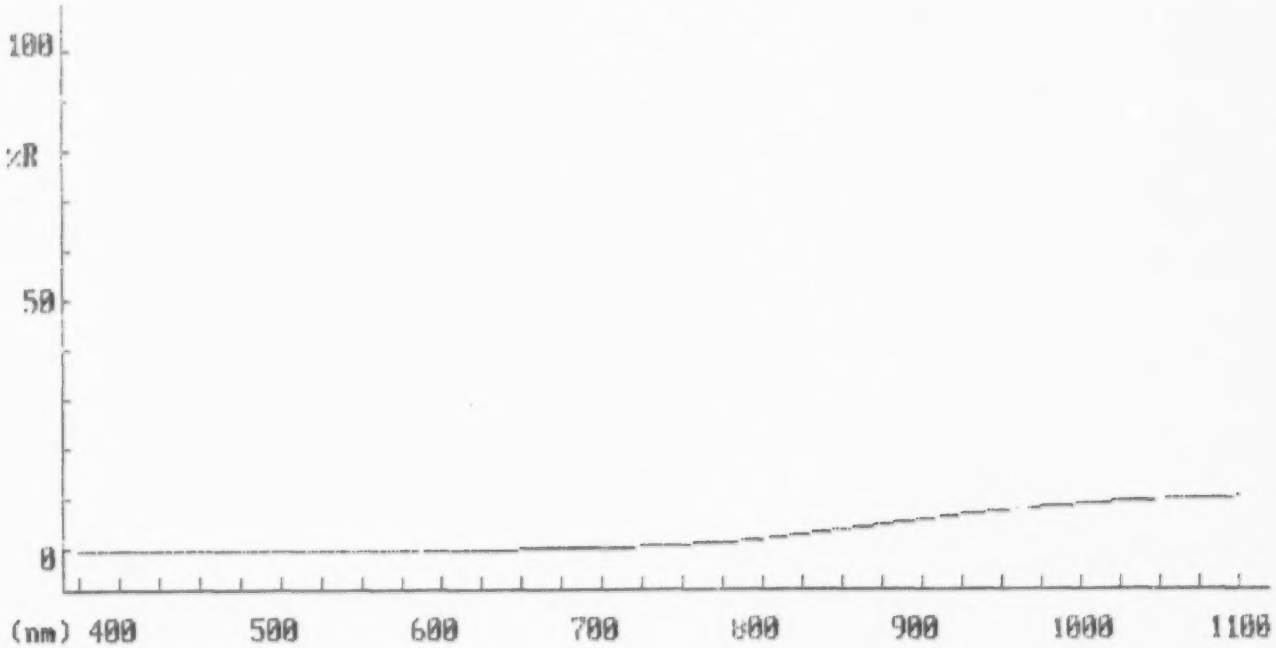
Data f[illegible] EX/UVL OFF/UVF OUT/LAV

——— STANDARD Ciba 10333 Black



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 15:24 16:Dec:9
RSEX/UVL OFF/UVF OUT/LA

STANDARD NAME: Ciba 10342 Kelly green #7AC
SAMPLE NAME:
10 DEGREE D65

	STD
L*	34.41
a*	-32.24
b*	18.16

W/L	Standard	W/L	Standard
400	1.44	760	15.54
410	1.58	770	17.75
420	1.77	780	19.41
430	2.08	790	20.32
440	2.55	800	20.85
450	3.29	810	21.16
460	4.31	820	21.47
470	5.57	830	21.91
480	7.04	840	22.50
490	8.62	850	23.13
500	10.12	860	23.72
510	11.36	870	24.22
520	12.66	880	24.61
530	13.37	890	24.89
540	13.03	900	25.10
550	11.44	910	25.21
560	9.08	920	25.25
570	6.52	930	25.21
580	4.67	940	25.12
590	3.84	950	24.95
600	3.48	960	24.72
610	3.05	970	24.42
620	2.57	980	24.07
630	2.41	990	23.67
640	2.45	1000	23.24
650	2.49	1010	22.79
660	2.52	1020	22.32
670	2.40	1030	21.84
680	2.32	1040	21.39
690	2.33	1050	20.95
700	2.78	1060	20.60
710	3.82	1070	20.26
720	5.92	1080	19.87
730	8.79	1090	19.50
740	11.53	1100	19.26
750	13.74		

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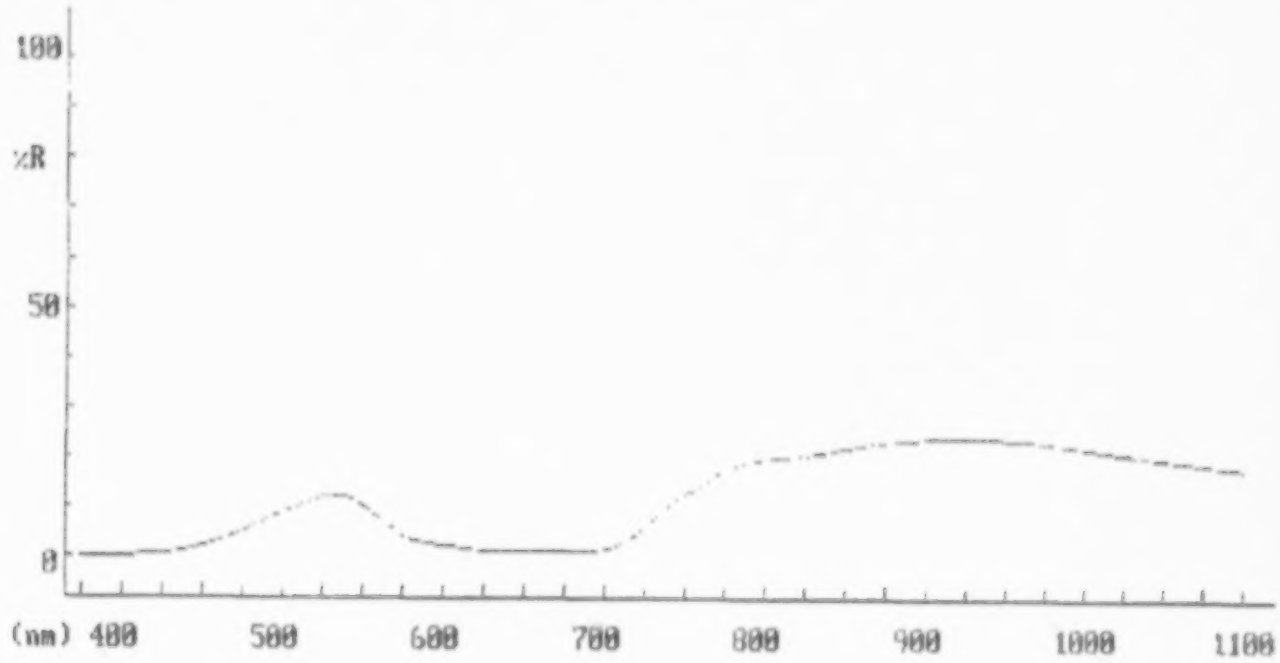
Data file:DND RSEX/UVL OFF/UVF OUT/LAV

STANDARD Ciba 10342 Kelly



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STANDARD NAME: Ciba 10405 green Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	26.63
a*	-27.22
b*	4.10

W/L	Standard	W/L	Standard
400	2.28	760	24.91
410	2.51	770	25.33
420	2.70	780	25.57
430	2.97	790	25.69
440	3.37	800	25.76
450	3.83	810	25.85
460	4.37	820	25.91
470	5.02	830	25.96
480	5.81	840	26.01
490	6.76	850	26.04
500	7.78	860	26.07
510	8.79	870	26.08
520	9.14	880	26.08
530	8.43	890	26.08
540	7.00	900	26.08
550	5.41	910	26.07
560	3.91	920	26.07
570	2.82	930	26.03
580	2.36	940	26.01
590	2.14	950	26.00
600	1.84	960	25.95
610	1.60	970	25.91
620	1.61	980	25.84
630	1.66	990	25.77
640	1.67	1000	25.70
650	1.60	1010	25.61
660	1.58	1020	25.51
670	1.82	1030	25.38
680	2.42	1040	25.24
690	3.80	1050	25.09
700	6.45	1060	24.94
710	10.63	1070	24.67
720	15.63	1080	24.31
730	19.81	1090	23.89
740	22.57	1100	23.50
750	24.24		

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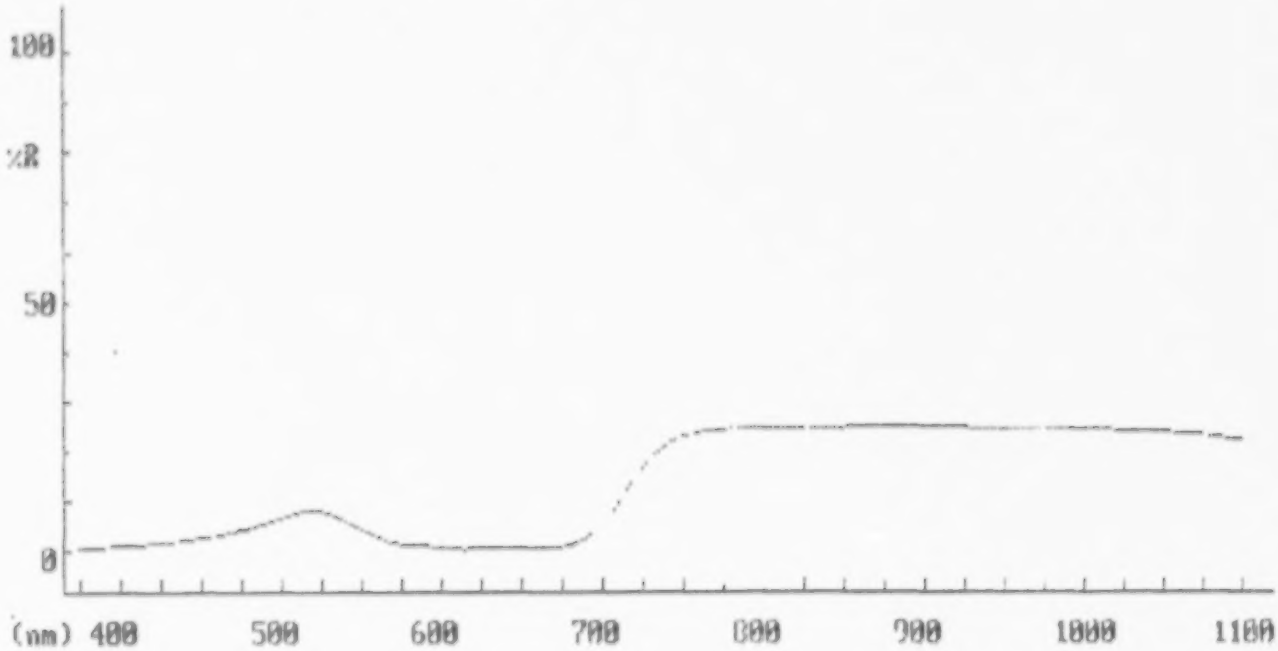
data file.dnd

STANDARD Ciba 10405 green



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan Specware, version 1.09
RSEX/UVL OFF/UVF OUT/LAV

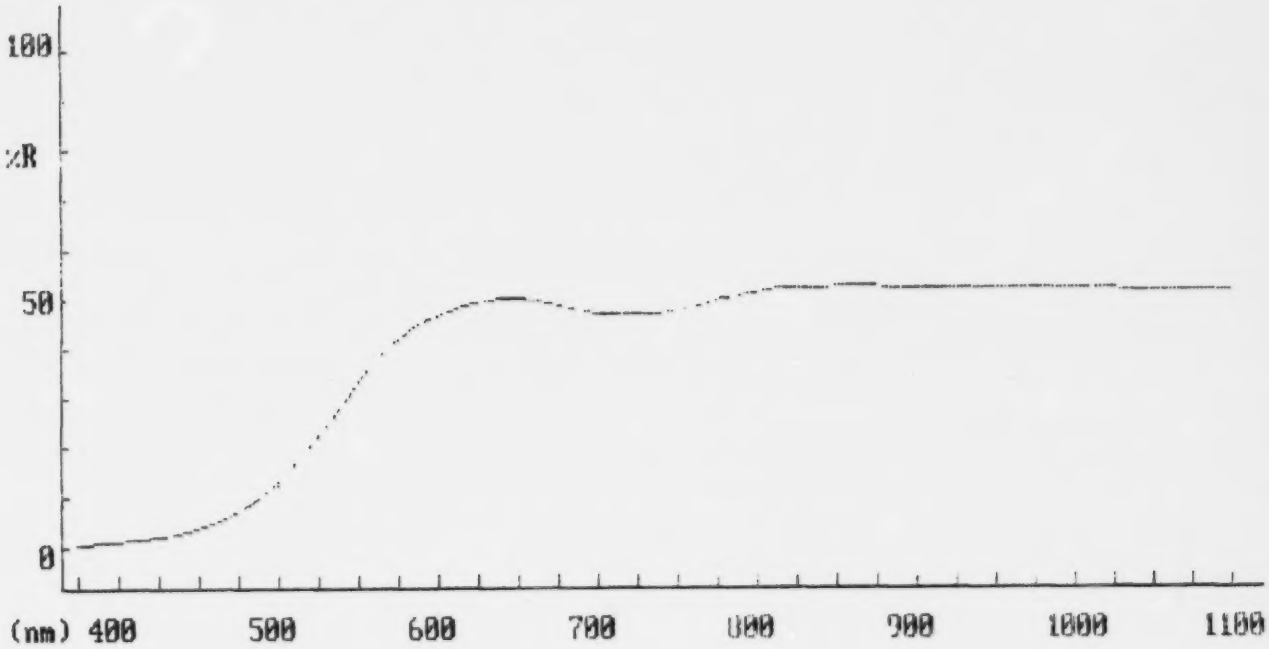
STANDARD NAME: Ciba 10406 yellow Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	63.87
a*	13.49
b*	59.19

W/L	Standard	W/L	Standard
400	2.53	760	49.50
410	2.85	770	50.39
420	3.16	780	51.29
430	3.61	790	52.01
440	4.23	800	52.60
450	5.08	810	53.06
460	6.17	820	53.35
470	7.59	830	53.52
480	9.39	840	53.62
490	11.63	850	53.66
500	14.37	860	53.67
510	17.60	870	53.66
520	21.32	880	53.63
530	25.42	890	53.60
540	29.77	900	53.58
550	34.15	910	53.55
560	38.29	920	53.51
570	41.81	930	53.48
580	44.49	940	53.47
590	46.44	950	53.45
600	47.86	960	53.42
610	49.06	970	53.38
620	50.05	980	53.34
630	50.79	990	53.28
640	51.13	1000	53.24
650	51.12	1010	53.20
660	50.78	1020	53.16
670	50.17	1030	53.12
680	49.45	1040	53.09
690	48.84	1050	53.07
700	48.27	1060	53.09
710	48.05	1070	53.04
720	47.94	1080	52.88
730	48.11	1090	52.71
740	48.33	1100	52.69
750	48.89		

Data file:DND RSEX/UVL OFF/UVF CUT/LPU

——— STANDARD Ciba 10406 yellio



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Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

15:28 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Ciba GLN green #4AC
SAMPLE NAME:
10 DEGREE D65

	STD
L*	9.63
a*	-9.01
b*	-4.72

W/L	Standard	W/L	Standard
400	0.88	760	1.69
410	0.93	770	1.63
420	0.98	780	1.59
430	1.04	790	1.62
440	1.09	800	1.75
450	1.20	810	1.99
460	1.45	820	2.34
470	1.89	830	2.82
480	2.48	840	3.50
490	3.06	850	4.38
500	2.90	860	5.52
510	2.12	870	6.87
520	1.40	880	8.35
530	0.94	890	9.87
540	0.69	900	11.36
550	0.59	910	12.76
560	0.56	920	14.13
570	0.58	930	15.44
580	0.62	940	16.83
590	0.67	950	18.66
600	0.71	960	21.01
610	0.77	970	23.46
620	0.80	980	25.75
630	0.79	990	27.86
640	0.83	1000	29.59
650	0.85	1010	30.61
660	0.88	1020	30.82
670	1.00	1030	30.50
680	1.01	1040	30.26
690	1.00	1050	30.37
700	0.98	1060	30.49
710	0.94	1070	29.98
720	0.99	1080	28.74
730	1.03	1090	26.93
740	1.14	1100	24.62
750	1.49		

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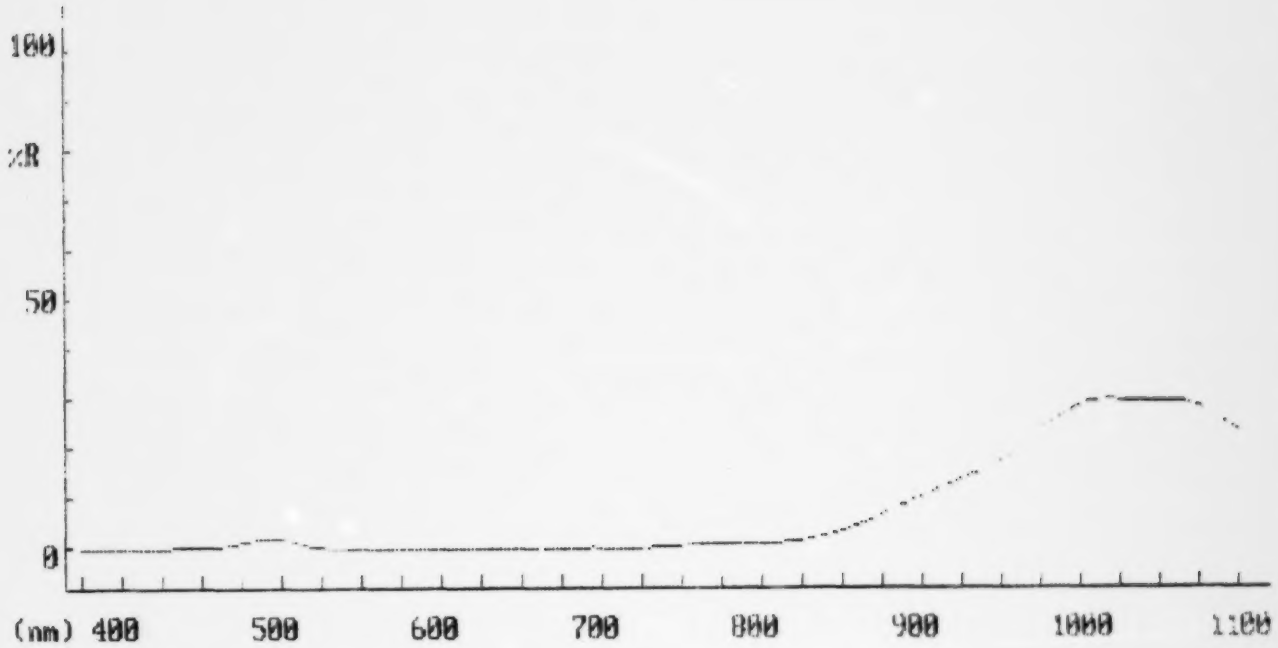
Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Ciba GLN green #



516888.PDF [Page: 102 of 183]

Report # 17-123-123:-1 (Title: ...t Reflective Coatings)
UltraScan SpecWare, Version 1.09 15:30 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

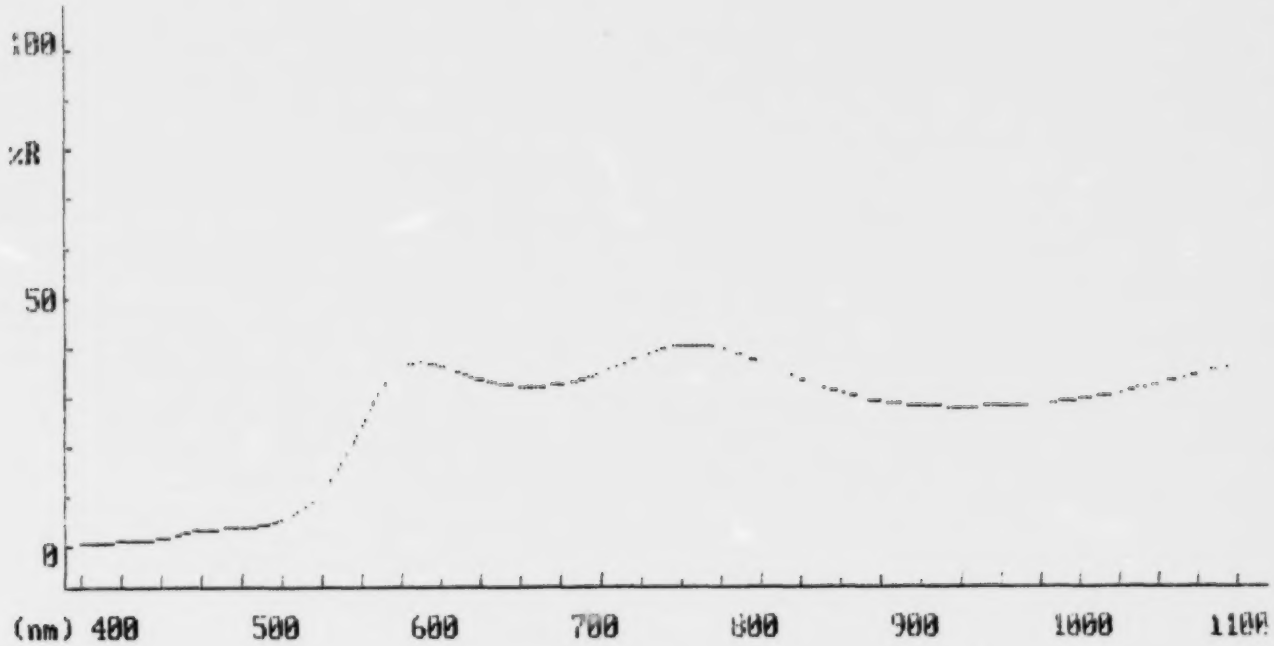
STANDARD NAME: Mass-Bayer 3910 #1AC
SAMPLE NAME:
10 DEGREE D65

	STD
L*	55.76
a*	16.94
b*	53.51

W/L	Standard	W/L	Standard
400	2.09	760	41.56
410	2.30	770	41.24
420	2.59	780	40.50
430	3.10	790	39.42
440	3.88	800	38.15
450	4.50	810	36.81
460	4.68	820	35.48
470	4.81	830	34.22
480	5.03	840	33.10
490	5.55	850	32.11
500	6.54	860	31.27
510	8.12	870	30.58
520	10.52	880	30.04
530	14.22	890	29.63
540	19.37	900	29.37
550	25.52	910	29.20
560	31.42	920	29.12
570	35.71	930	29.11
580	37.79	940	29.19
590	38.05	950	29.34
600	37.30	960	29.51
610	36.20	970	29.74
620	35.09	980	30.03
630	34.16	990	30.37
640	33.54	1000	30.78
650	33.26	1010	31.26
660	33.20	1020	31.77
670	33.50	1030	32.37
680	34.01	1040	33.04
690	34.85	1050	33.79
700	35.98	1060	34.65
710	37.32	1070	35.52
720	38.71	1080	36.28
730	39.99	1090	37.03
740	41.00	1100	38.07
750	41.57		

Data file:DND

STANDARD Mass-Bayer 3410



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

15:32 16:Dec:9

RSEX/UVL OFF/UVF OUT/LAV

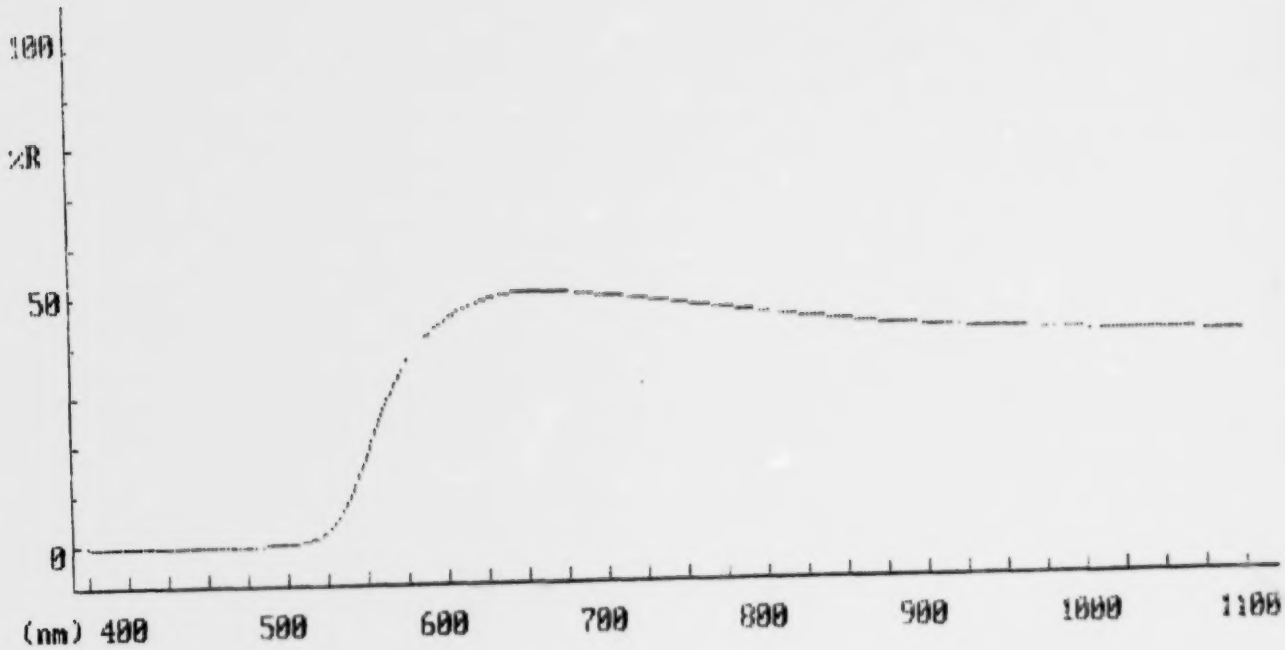
STANDARD NAME: Mass-Ciba 3RLTN #3AC
SAMPLE NAME:
10 DEGREE DOS

	STD
L*	54.36
a*	36.73
b*	80.39

W/L	Standard	W/L	Standard
400	0.64	760	48.14
410	0.64	770	47.75
420	0.68	780	47.40
430	0.71	790	47.01
440	0.72	800	46.63
450	0.76	810	46.26
460	0.84	820	45.90
470	0.91	830	45.56
480	0.99	840	45.25
490	1.08	850	44.94
500	1.27	860	44.64
510	1.69	870	44.33
520	2.75	880	44.08
530	5.34	890	43.89
540	10.67	900	43.67
550	18.83	910	43.44
560	27.66	920	43.28
570	34.88	930	43.18
580	39.94	940	43.10
590	43.47	950	42.99
600	45.98	960	42.83
610	47.94	970	42.66
620	49.44	980	42.50
630	50.41	990	42.34
640	51.02	1000	42.21
650	51.34	1010	42.08
660	51.43	1020	41.95
670	51.27	1030	41.84
680	50.91	1040	41.77
690	50.60	1050	41.69
700	50.37	1060	41.70
710	50.10	1070	41.69
720	49.73	1080	41.56
730	49.38	1090	41.35
740	49.00	1100	41.23
750	48.57		

Data file:DND %SEX/UUL OFF/UUF OUT/LAV

STANDARD Mass-Ciba ERLTN



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Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

15:34 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

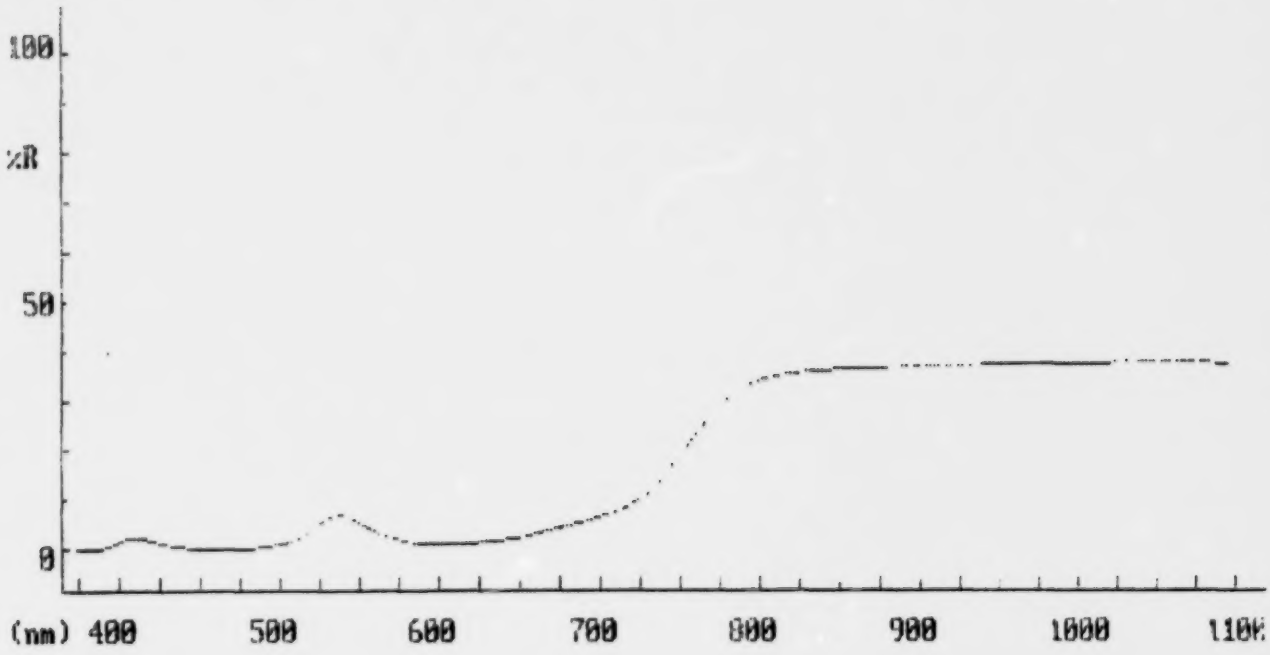
STANDARD NAME: Bayer 5303 Green #2AC
SAMPLE NAME:
10 DEGREE D65

	STD
L*	24.05
a*	-14.12
b*	17.32

W/L	Standard	W/L	Standard
400	2.63	760	24.22
410	3.53	770	28.26
420	2.89	780	31.54
430	2.07	790	33.84
440	1.58	800	35.32
450	1.36	810	36.20
460	1.29	820	36.73
470	1.31	830	37.11
480	1.43	840	37.38
490	1.76	850	37.59
500	2.27	860	37.75
510	3.13	870	37.87
520	5.05	880	38.00
530	7.37	890	38.11
540	7.86	900	38.22
550	6.47	910	38.30
560	4.75	920	38.40
570	3.47	930	38.48
580	2.75	940	38.58
590	2.37	950	38.68
600	2.27	960	38.74
610	2.32	970	38.80
620	2.48	980	38.85
630	2.73	990	38.89
640	3.11	1000	38.96
650	3.61	1010	39.01
660	4.25	1020	39.05
670	5.18	1030	39.12
680	5.90	1040	39.18
690	6.79	1050	39.23
700	7.74	1060	39.30
710	8.83	1070	39.28
720	10.44	1080	39.16
730	12.71	1090	39.04
740	15.71	1100	39.12
750	20.15		

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Bayer 5303 Green



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Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

15:48 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Harshaw Bl 9885 Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	16.24
a*	2.93
b*	5.35

W/L	Standard	W/L	Standard
400	1.81	760	11.14
410	2.01	770	12.33
420	1.91	780	13.83
430	1.68	790	15.59
440	1.55	800	17.55
450	1.49	810	19.56
460	1.46	820	21.45
470	1.43	830	23.12
480	1.54	840	24.44
490	1.65	850	25.42
500	1.75	860	26.12
510	1.88	870	26.54
520	2.05	880	26.76
530	2.16	890	26.88
540	2.20	900	26.91
550	2.19	910	26.91
560	2.14	920	26.89
570	2.06	930	26.87
580	2.07	940	26.89
590	2.12	950	26.92
600	2.23	960	27.00
610	2.41	970	27.10
620	2.69	980	27.25
630	3.06	990	27.44
640	3.46	1000	27.69
650	3.88	1010	27.97
660	4.37	1020	28.25
670	4.92	1030	28.60
680	5.31	1040	28.96
690	5.63	1050	29.36
700	6.06	1060	29.77
710	6.48	1070	30.04
720	7.12	1080	30.21
730	7.86	1090	30.42
740	8.62	1100	30.93
750	9.96		

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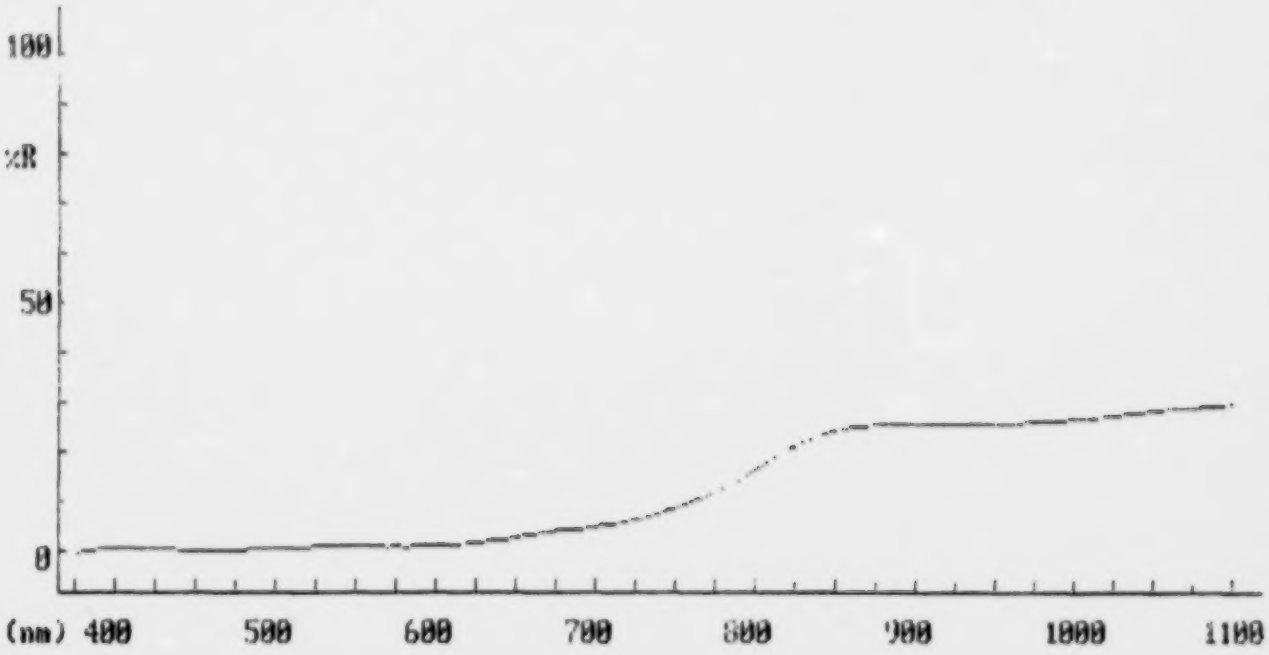
Data file:DMD RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Harshaw B1 9885



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Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 15:51 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

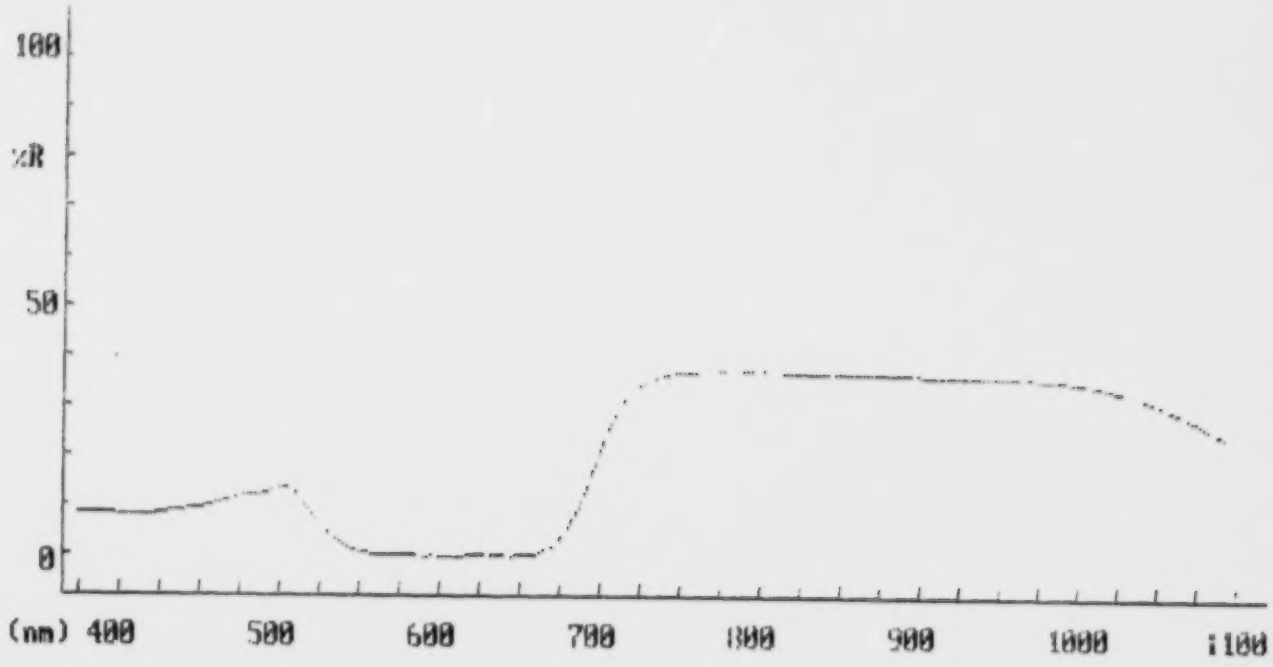
STANDARD NAME: Ferro V9238 Blue Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	26.49
a*	-21.30
b*	-23.04

W/L	Standard	W/L	Standard
400	9.29	760	38.01
410	8.95	770	38.13
420	9.23	780	38.17
430	9.91	790	38.13
440	10.36	800	38.06
450	10.78	810	38.01
460	11.60	820	37.92
470	12.63	830	37.84
480	13.30	840	37.77
490	13.67	850	37.70
500	14.84	860	37.65
510	13.59	870	37.60
520	9.65	880	37.55
530	5.76	890	37.52
540	3.25	900	37.50
550	1.93	910	37.48
560	1.41	920	37.45
570	1.23	930	37.41
580	1.11	940	37.38
590	1.01	950	37.31
600	0.98	960	37.19
610	0.98	970	37.03
620	1.06	980	36.82
630	1.02	990	36.53
640	1.05	1000	36.17
650	1.13	1010	35.68
660	1.54	1020	35.05
670	3.05	1030	34.28
680	6.68	1040	33.31
690	13.36	1050	32.17
700	22.17	1060	30.90
710	29.71	1070	29.45
720	34.05	1080	27.89
730	36.22	1090	26.23
740	37.25	1100	24.40
750	37.84		

Data file:DND RSEX/UVL OFF/UVF OUT/LPU

STANDARD ferro 09238 Blue



Report # 97-T23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 16:03 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Ferro V12600 green Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	27.10
a*	-27.68
b*	6.96

W/L	Standard	W/L	Standard
400	2.08	760	39.54
410	2.28	770	41.04
420	2.44	780	41.97
430	2.65	790	42.52
440	2.97	800	42.90
450	3.42	810	43.21
460	3.96	820	43.44
470	4.59	830	43.64
480	5.45	840	43.83
490	6.47	850	44.01
500	7.62	860	44.19
510	8.79	870	44.36
520	9.36	880	44.51
530	8.84	890	44.67
540	7.47	900	44.81
550	5.81	910	44.94
560	4.20	920	45.05
570	3.03	930	45.13
580	2.57	940	45.21
590	2.33	950	45.24
600	1.99	960	45.23
610	1.69	970	45.19
620	1.66	980	45.12
630	1.77	990	45.01
640	1.79	1000	44.86
650	1.67	1010	44.65
660	1.61	1020	44.39
670	1.81	1030	44.07
680	2.35	1040	43.67
690	3.63	1050	43.20
700	6.36	1060	42.66
710	11.28	1070	41.93
720	18.27	1080	40.99
730	25.91	1090	39.86
740	32.39	1100	38.76
750	37.21		

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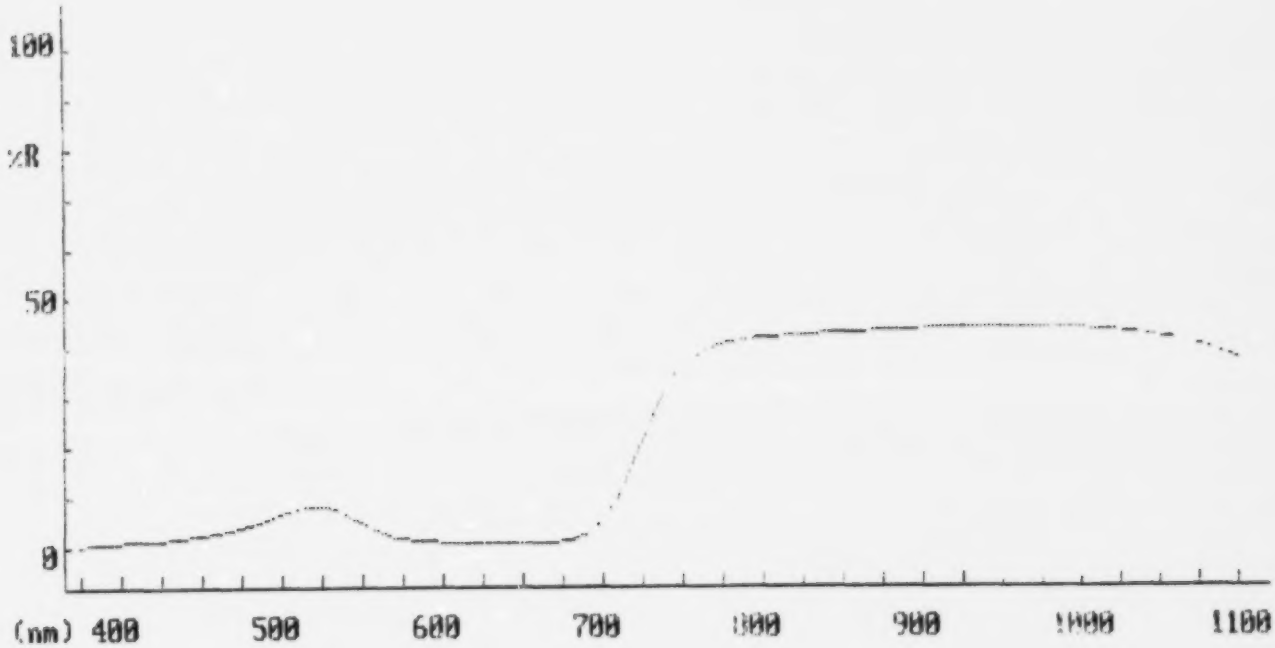
Data file:DND [illegible]/BUL OFF/BUF OUT/LAU

——— STANDARD Ferro b12600 gre



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

16:02 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: BASF L0086 BL Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	7.44
a*	-1.58
b*	-0.37

W/L	Standard	W/L	Standard
400	0.74	760	20.18
410	0.85	770	24.48
420	0.84	780	26.67
430	0.80	790	27.42
440	0.81	800	27.57
450	0.85	810	27.56
460	0.85	820	27.45
470	0.83	830	27.38
480	0.89	840	27.33
490	0.90	850	27.32
500	0.89	860	27.41
510	0.89	870	27.53
520	0.90	880	27.71
530	0.89	890	27.95
540	0.87	900	28.22
550	0.86	910	28.53
560	0.82	920	28.85
570	0.76	930	29.18
580	0.75	940	29.53
590	0.74	950	29.87
600	0.72	960	30.20
610	0.67	970	30.53
620	0.69	980	30.86
630	0.70	990	31.18
640	0.71	1000	31.51
650	0.70	1010	31.83
660	0.73	1020	32.13
670	0.84	1030	32.43
680	0.97	1040	32.72
690	1.16	1050	33.03
700	1.60	1060	33.30
710	2.25	1070	33.43
720	3.45	1080	33.41
730	5.51	1090	33.41
740	9.01	1100	33.72
750	14.88		

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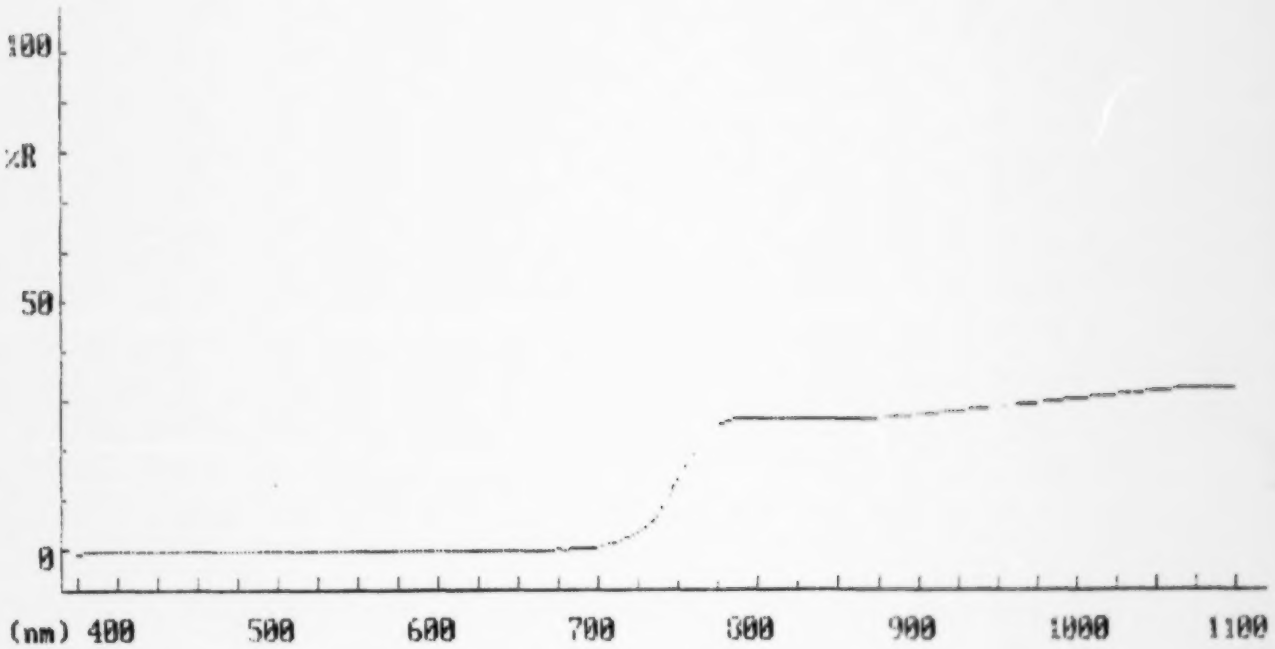
Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD BASF L0086 BL Ma



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
Ultrascan Specware, Version 1.09

16:05 16:Dec:9t
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Ferro V11674 green Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	35.60
a*	-18.28
b*	20.55

W/L	Standard	W/L	Standard
400	7.26	760	35.75
410	9.54	770	38.95
420	7.40	780	41.02
430	4.93	790	42.13
440	3.55	800	42.67
450	2.96	810	42.89
460	2.78	820	42.95
470	2.84	830	42.93
480	3.27	840	42.89
490	4.14	850	42.86
500	5.36	860	42.83
510	7.30	870	42.78
520	11.34	880	42.75
530	15.60	890	42.72
540	16.22	900	42.71
550	13.49	910	42.70
560	10.07	920	42.68
570	7.42	930	42.66
580	5.82	940	42.66
590	5.02	950	42.65
600	4.78	960	42.62
610	4.91	970	42.59
620	5.29	980	42.56
630	5.86	990	42.53
640	6.58	1000	42.50
650	7.56	1010	42.47
660	8.99	1020	42.43
670	10.58	1030	42.41
680	12.01	1040	42.37
690	13.44	1050	42.36
700	15.07	1060	42.38
710	16.89	1070	42.33
720	19.46	1080	42.16
730	22.84	1090	41.97
740	26.83	1100	42.00
750	31.84		

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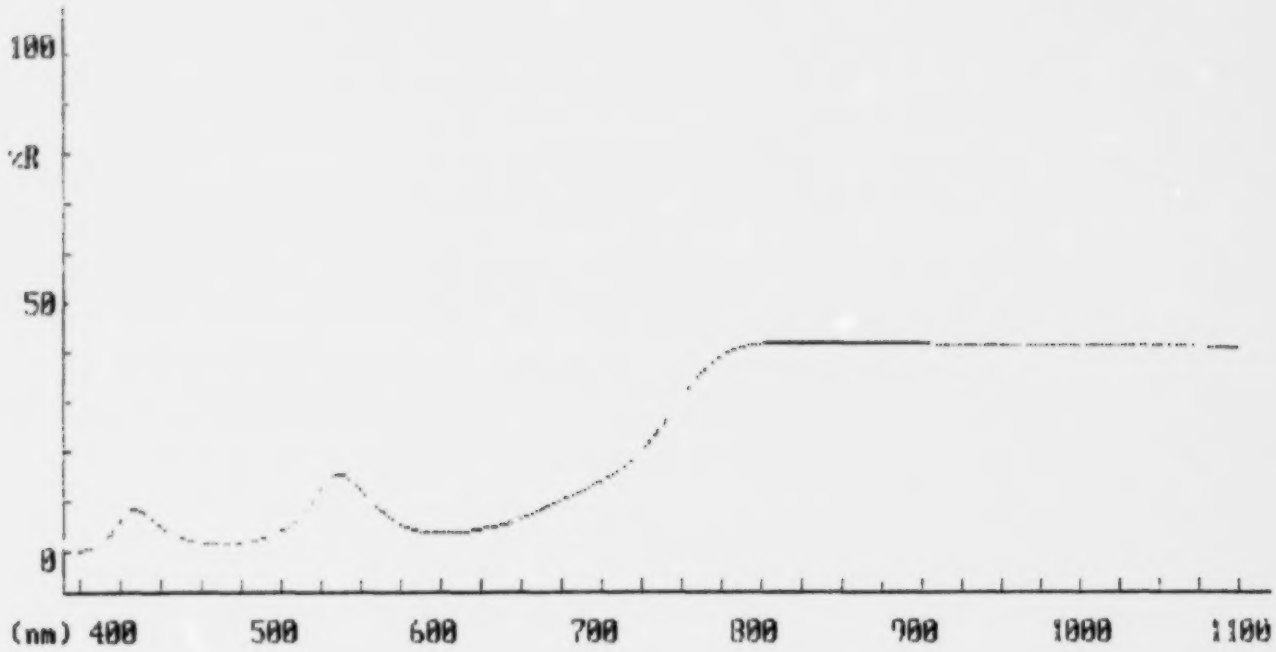
Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Ferro U11674 gre



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

16:06 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: BASF L0084 BL Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	12.52
a*	1.15
b*	0.22

W/L	Standard	W/L	Standard
400	1.38	760	39.71
410	1.47	770	40.17
420	1.47	780	40.49
430	1.42	790	40.66
440	1.42	800	40.86
450	1.47	810	41.12
460	1.48	820	41.39
470	1.45	830	41.71
480	1.51	840	42.12
490	1.50	850	42.66
500	1.49	860	43.34
510	1.49	870	44.11
520	1.50	880	45.00
530	1.49	890	45.94
540	1.47	900	46.93
550	1.45	910	47.92
560	1.42	920	48.93
570	1.38	930	49.92
580	1.40	940	50.90
590	1.40	950	51.86
600	1.40	960	52.74
610	1.41	970	53.59
620	1.46	980	54.38
630	1.51	990	55.13
640	1.66	1000	55.86
650	1.90	1010	56.54
660	2.53	1020	57.19
670	3.64	1030	57.78
680	5.32	1040	58.35
690	8.78	1050	58.87
700	15.38	1060	59.31
710	23.88	1070	59.54
720	30.75	1080	59.59
730	34.82	1090	59.70
740	37.15	1100	60.21
750	38.89		

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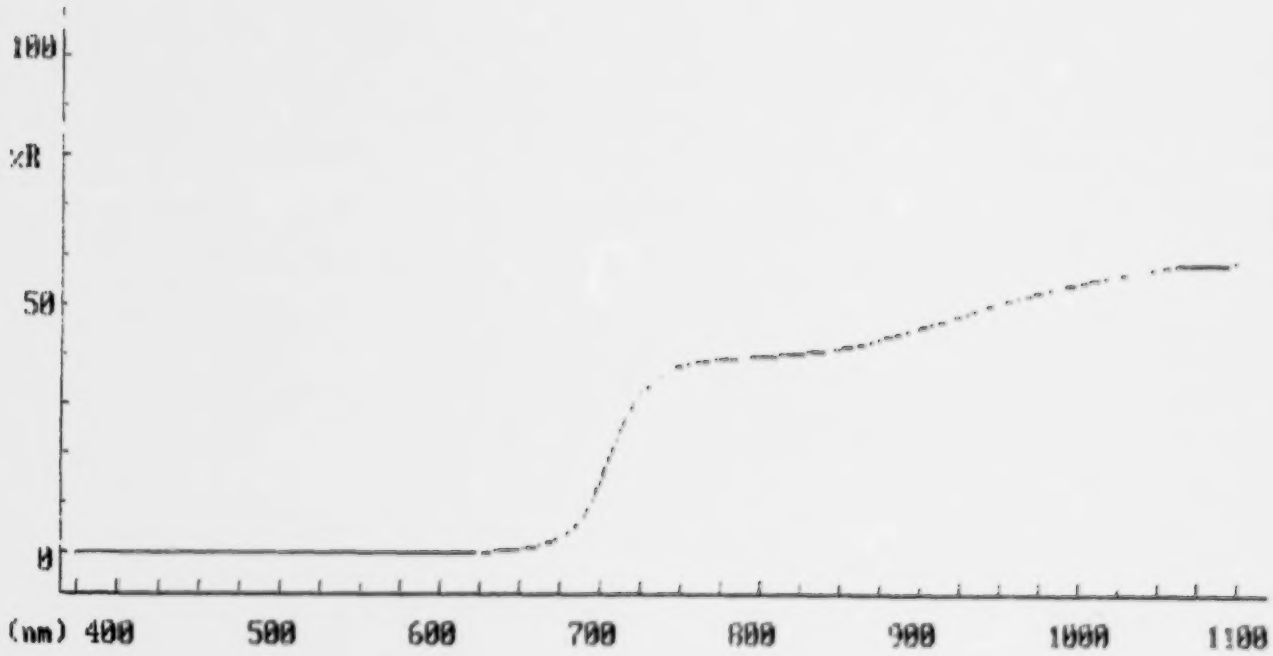
Data file:DND PSEX/UVL OFF/UVF OUT/LAV

STANDARD BASF L0084 BL Ma



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

16:07 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

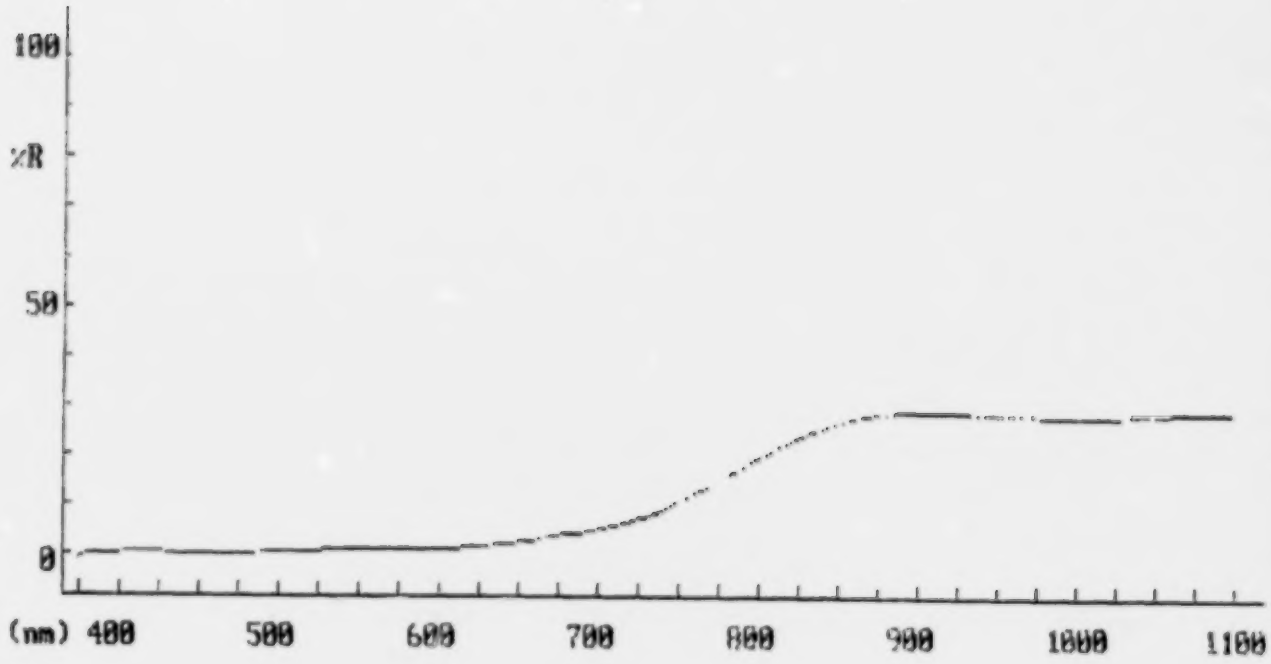
STANDARD NAME: Ferro V-700 BL Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	16.47
a*	3.25
b*	6.50

W/L	Standard	W/L	Standard
400	1.56	760	13.73
410	1.77	770	15.44
420	1.71	780	17.26
430	1.55	790	19.08
440	1.46	800	20.88
450	1.45	810	22.62
460	1.43	820	24.26
470	1.41	830	25.77
480	1.51	840	27.08
490	1.60	850	28.17
500	1.69	860	29.06
510	1.81	870	29.68
520	1.95	880	30.09
530	2.11	890	30.33
540	2.19	900	30.44
550	2.25	910	30.44
560	2.27	920	30.37
570	2.24	930	30.25
580	2.28	940	30.12
590	2.31	950	29.98
600	2.40	960	29.85
610	2.54	970	29.72
620	2.77	980	29.63
630	3.04	990	29.56
640	3.39	1000	29.55
650	3.71	1010	29.56
660	4.16	1020	29.61
670	4.81	1030	29.70
680	5.32	1040	29.82
690	5.75	1050	30.00
700	6.32	1060	30.22
710	6.93	1070	30.34
720	7.85	1080	30.37
730	8.93	1090	30.44
740	10.13	1100	30.79
750	12.04		

Data File:2NB RSEX/UVL OFF/UVF OUT/LAV

STANDARD Ferro U-700 BL M



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 16:09 16:Dec:9

RSEX/UVL OFF/UVF OUT/LAV

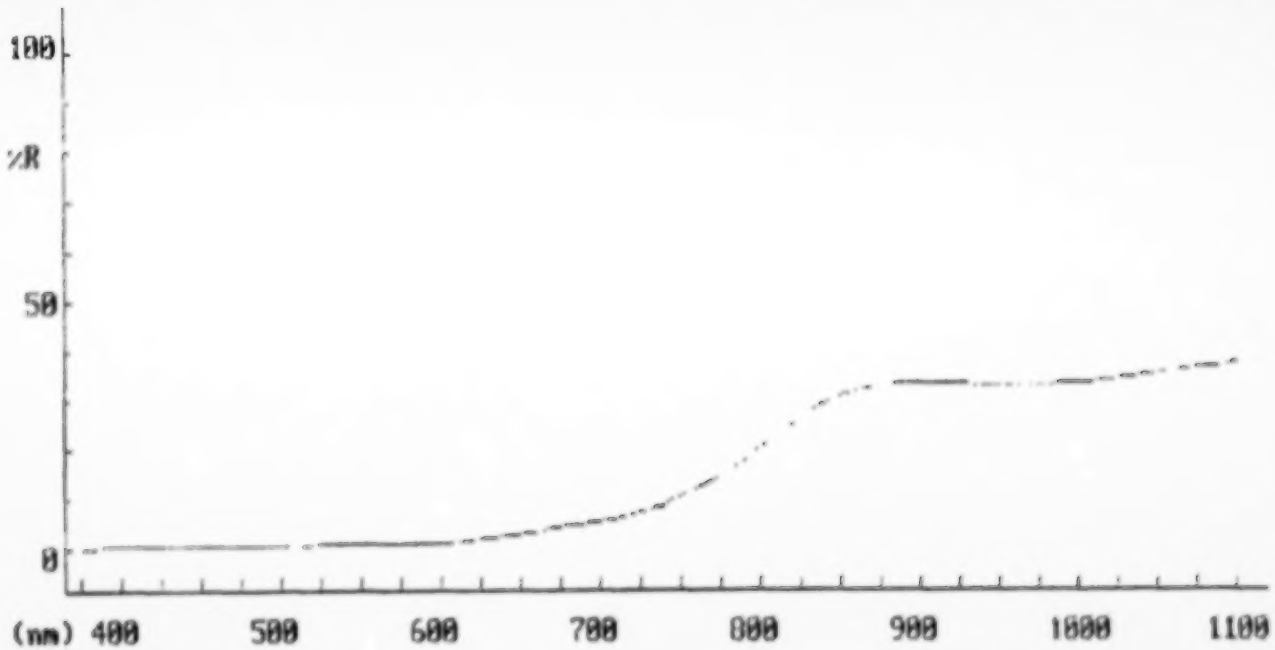
STANDARD NAME: Shep. BL #123 Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	16.89
a*	4.08
b*	4.98

W/L	Standard	W/L	Standard
400	1.95	760	13.35
410	2.08	770	15.01
420	2.00	780	16.97
430	1.81	790	19.19
440	1.70	800	21.62
450	1.65	810	24.13
460	1.63	820	26.55
470	1.60	830	28.74
480	1.69	840	30.59
490	1.76	850	32.06
500	1.84	860	33.16
510	1.93	870	33.88
520	2.07	880	34.31
530	2.17	890	34.53
540	2.22	900	34.59
550	2.26	910	34.57
560	2.26	920	34.48
570	2.24	930	34.38
580	2.29	940	34.29
590	2.34	950	34.24
600	2.48	960	34.21
610	2.67	970	34.23
620	2.97	980	34.32
630	3.36	990	34.45
640	3.74	1000	34.66
650	4.18	1010	34.92
660	4.68	1020	35.23
670	5.28	1030	35.60
680	5.79	1040	36.04
690	6.17	1050	36.51
700	6.75	1060	37.02
710	7.24	1070	37.40
720	8.01	1080	37.70
730	8.96	1090	38.04
740	9.99	1100	38.75
750	11.78		

Data file:DND RSEX/IVL OFF/UVF OUT/LAV

——— STANDARD Shep. BL #123 Ma



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

16:14 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

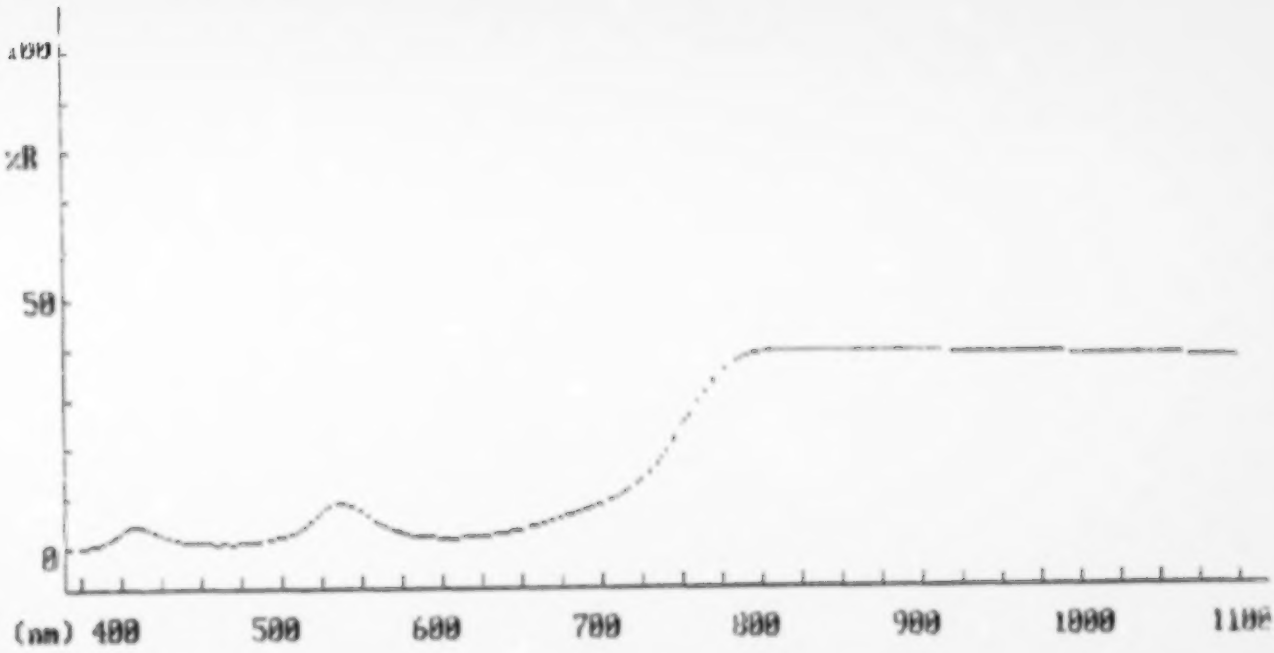
STANDARD NAME: Ferro V 11692 green Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	28.08
a*	-14.99
b*	15.96

W/L	Standard	W/L	Standard
400	4.32	760	30.02
410	5.65	770	34.30
420	4.50	780	37.39
430	3.16	790	39.20
440	2.47	800	40.11
450	2.18	810	40.50
460	2.06	820	40.60
470	2.06	830	40.60
480	2.28	840	40.55
490	2.72	850	40.49
500	3.36	860	40.44
510	4.44	870	40.36
520	6.86	880	40.29
530	9.67	890	40.23
540	10.16	900	40.17
550	8.36	910	40.12
560	6.19	920	40.06
570	4.58	930	40.00
580	3.64	940	39.96
590	3.20	950	39.90
600	3.06	960	39.83
610	3.11	970	39.76
620	3.31	980	39.67
630	3.62	990	39.59
640	4.06	1000	39.52
650	4.67	1010	39.44
660	5.46	1020	39.35
670	6.58	1030	39.27
680	7.57	1040	39.20
690	8.51	1050	39.13
700	9.76	1060	39.11
710	11.18	1070	39.01
720	13.28	1080	38.77
730	16.24	1090	38.56
740	19.98	1100	38.54
750	25.30		

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Ferro U 11692 gr



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

16:16 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Shep. Rutile #195 yellow Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	79.18
a*	-8.06
b*	50.17

W/L	Standard	W/L	Standard
400	3.38	760	55.72
410	4.56	770	56.01
420	6.15	780	56.26
430	8.31	790	56.42
440	11.41	800	56.65
450	15.48	810	56.90
460	20.50	820	57.14
470	26.46	830	57.37
480	32.97	840	57.67
490	39.47	850	58.15
500	45.37	860	58.75
510	50.26	870	59.32
520	54.10	880	59.81
530	56.98	890	60.23
540	59.01	900	60.57
550	60.28	910	60.85
560	61.02	920	61.06
570	61.47	930	61.23
580	61.68	940	61.37
590	61.79	950	61.45
600	61.65	960	61.46
610	61.31	970	61.45
620	60.78	980	61.40
630	60.10	990	61.34
640	59.32	1000	61.25
650	58.61	1010	61.15
660	57.88	1020	61.04
670	57.31	1030	60.93
680	56.91	1040	60.82
690	56.58	1050	60.75
700	56.32	1060	60.67
710	56.07	1070	60.55
720	55.80	1080	60.33
730	55.45	1090	60.08
740	55.08	1100	60.06
750	55.37		

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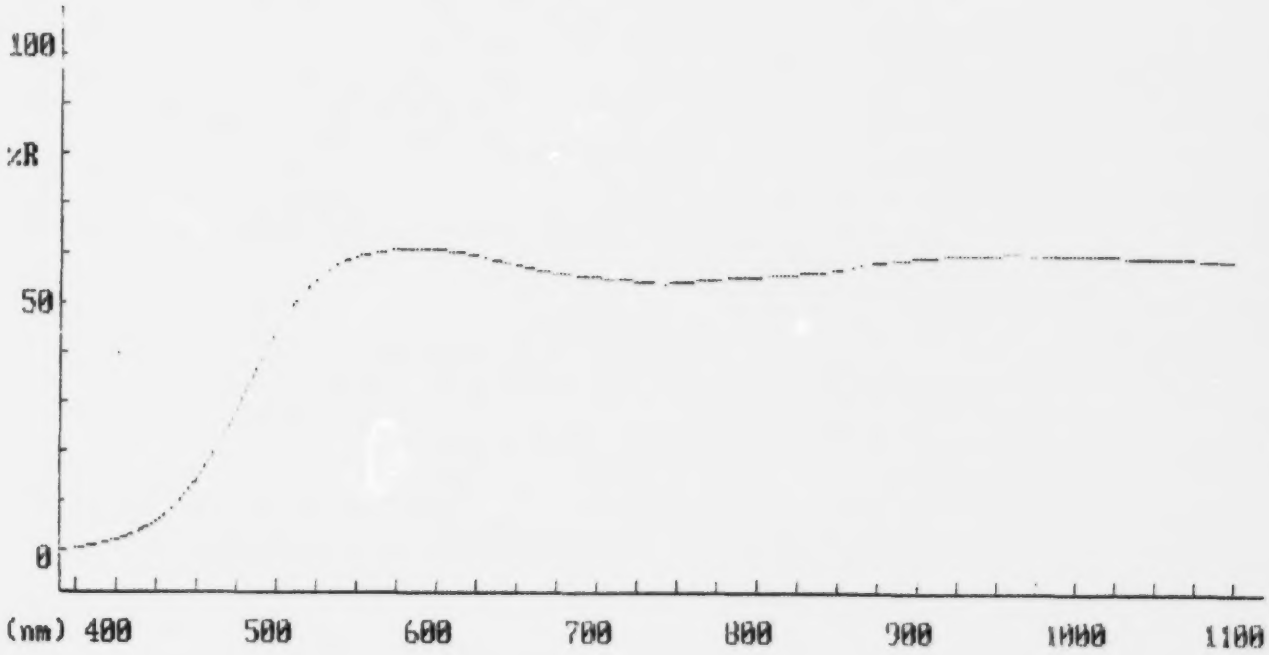
Data file:DND [illegible]

STANDARD Shep. Rutile 419



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, version 1.09
16:17 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Harcros G6099 green Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	39.43
a*	-18.76
b*	20.68

W/L	Standard	W/L	Standard
400	9.78	760	32.33
410	12.51	770	34.03
420	9.83	780	35.02
430	6.59	790	35.46
440	4.67	800	35.63
450	3.83	810	35.62
460	3.59	820	35.53
470	3.71	830	35.42
480	4.32	840	35.28
490	5.52	850	35.15
500	7.16	860	35.03
510	9.59	870	34.88
520	14.26	880	34.74
530	18.73	890	34.61
540	19.21	900	34.49
550	16.28	910	34.38
560	12.48	920	34.26
570	9.38	930	34.15
580	7.43	940	34.05
590	6.45	950	33.94
600	6.15	960	33.82
610	6.30	970	33.71
620	6.78	980	33.61
630	7.47	990	33.51
640	8.29	1000	33.40
650	9.44	1010	33.32
660	10.92	1020	33.21
670	12.69	1030	33.12
680	14.18	1040	33.04
690	15.54	1050	33.00
700	17.02	1060	32.99
710	18.68	1070	32.92
720	20.96	1080	32.76
730	23.74	1090	32.57
740	26.70	1100	32.56
750	30.04		

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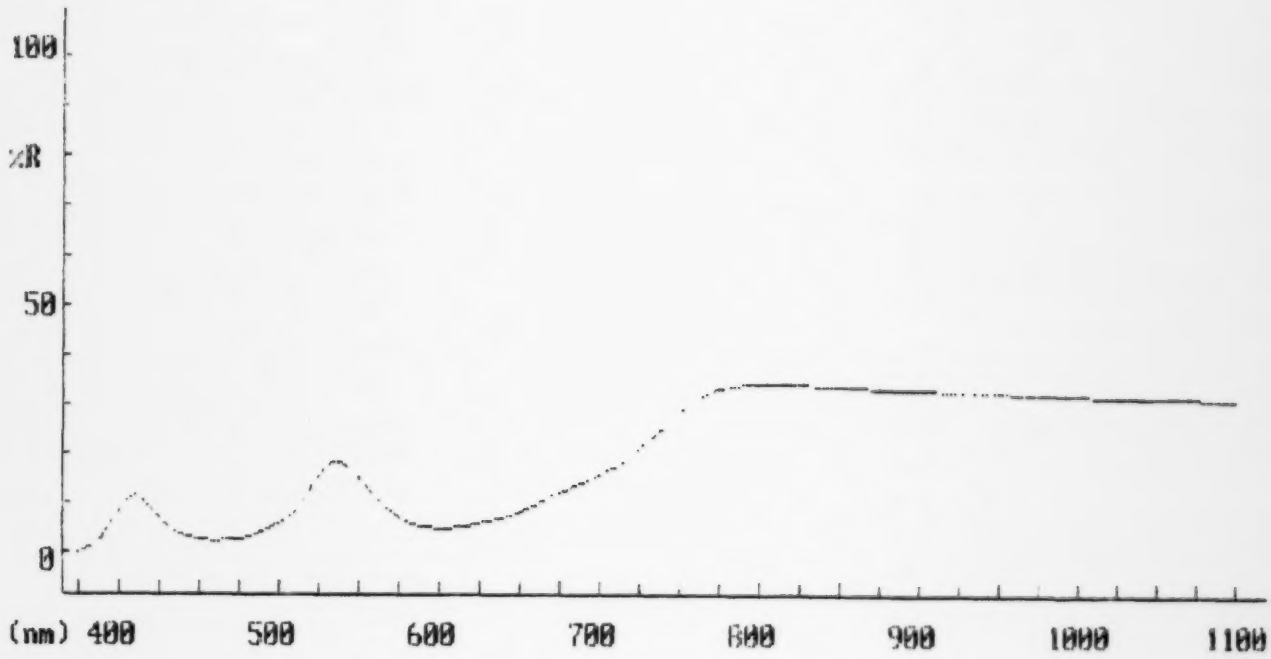
Data file:DND

STANDARD Harcros G6099 gr



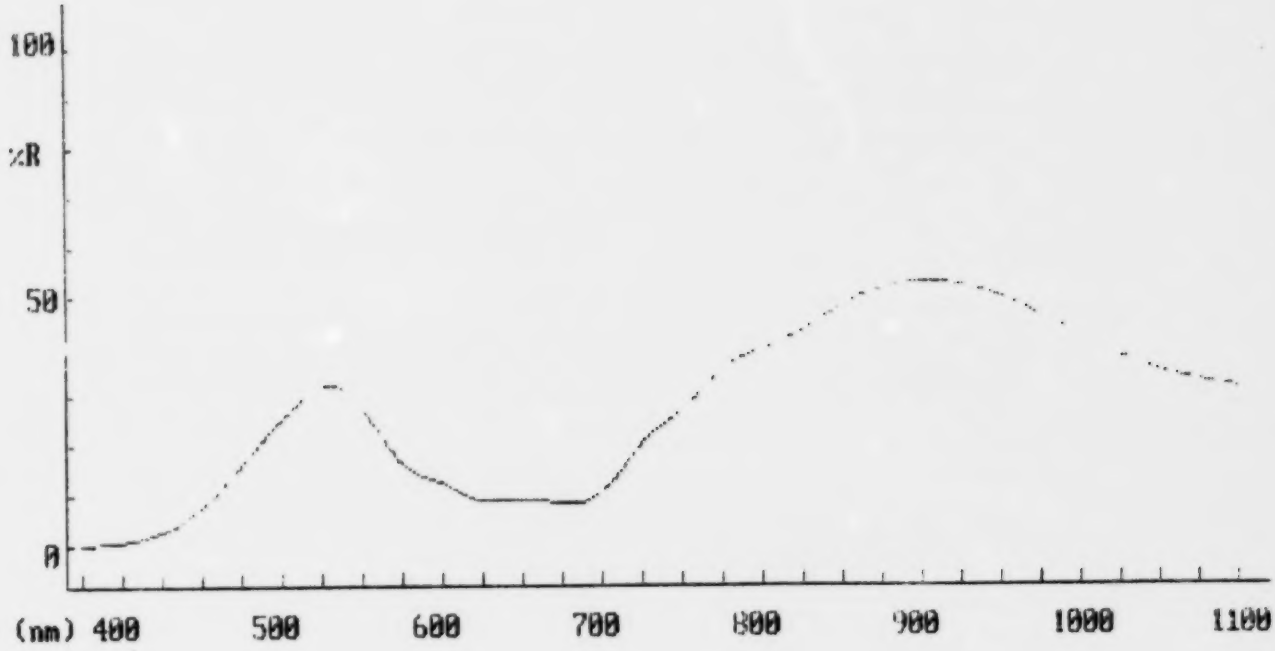
STANDARD NAME: Shep. #4 green Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	54.43
a*	-35.29
b*	26.97

W/L	Standard	W/L	Standard
400	1.99	760	31.05
410	2.58	770	34.71
420	3.37	780	37.41
430	4.55	790	39.11
440	6.36	800	40.40
450	8.81	810	41.71
460	11.75	820	43.28
470	15.14	830	45.13
480	18.89	840	47.09
490	22.72	850	49.02
500	26.25	860	50.75
510	29.38	870	52.14
520	32.07	880	53.15
530	33.07	890	53.78
540	31.88	900	54.05
550	28.60	910	54.00
560	24.08	920	53.64
570	19.37	930	52.99
580	16.28	940	52.12
590	14.71	950	50.99
600	13.59	960	49.65
610	11.84	970	48.14
620	10.41	980	46.54
630	10.03	990	44.89
640	10.15	1000	43.23
650	10.29	1010	41.60
660	10.04	1020	40.04
670	9.72	1030	38.57
680	9.51	1040	37.24
690	9.96	1050	36.09
700	11.70	1060	35.17
710	14.79	1070	34.44
720	19.06	1080	33.78
730	22.89	1090	33.19
740	25.28	1100	32.67
750	27.87		

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Shep. #4 green M



Report # 97-123-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 16:22 16:Dec:96
RSEX/UVL OFF/UVF OUT/AV

STANDARD NAME: Shep. #179 green Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	25.75
a*	-25.79
b*	3.33

W/L	Standard	W/L	Standard
400	2.39	760	25.87
410	2.62	770	26.47
420	2.77	780	26.86
430	2.97	790	27.09
440	3.30	800	27.29
450	3.73	810	27.46
460	4.21	820	27.61
470	4.76	830	27.77
480	5.50	840	27.90
490	6.36	850	28.02
500	7.30	860	28.14
510	8.22	870	28.23
520	8.52	880	28.31
530	7.84	890	28.38
540	6.50	900	28.46
550	5.03	910	28.52
560	3.65	920	28.56
570	2.66	930	28.59
580	2.28	940	28.62
590	2.07	950	28.63
600	1.78	960	28.62
610	1.54	970	28.58
620	1.54	980	28.54
630	1.60	990	28.47
640	1.59	1000	28.40
650	1.50	1010	28.30
660	1.40	1020	28.15
670	1.69	1030	27.99
680	2.15	1040	27.78
690	3.28	1050	27.57
700	5.69	1060	27.32
710	9.66	1070	26.92
720	14.72	1080	26.39
730	19.37	1090	25.78
740	22.69	1100	25.19
750	24.91		

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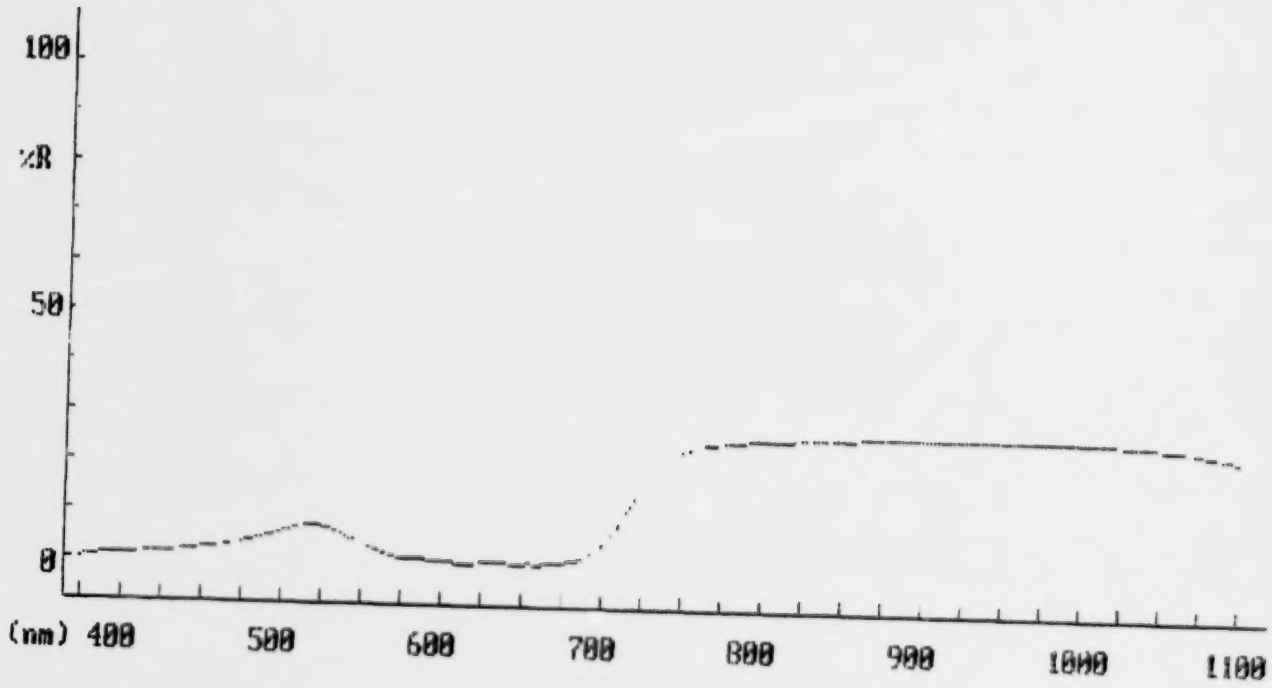
Data file:DND RSEX/1NM OFF/1UF OUT/1PU

STANDARD Shep. #179 green



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09 16:26 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: General Marine std
SAMPLE NAME: 7222-55
10 DEGREE D65

	STD	SAM
L*	74.75	74.80
a*	-6.07	-5.60
b*	1.20	0.19

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS EQ. LIGHT, LESS GREEN, AND BLUER

DE*	DC*	DH*
1.12	-0.59	0.95

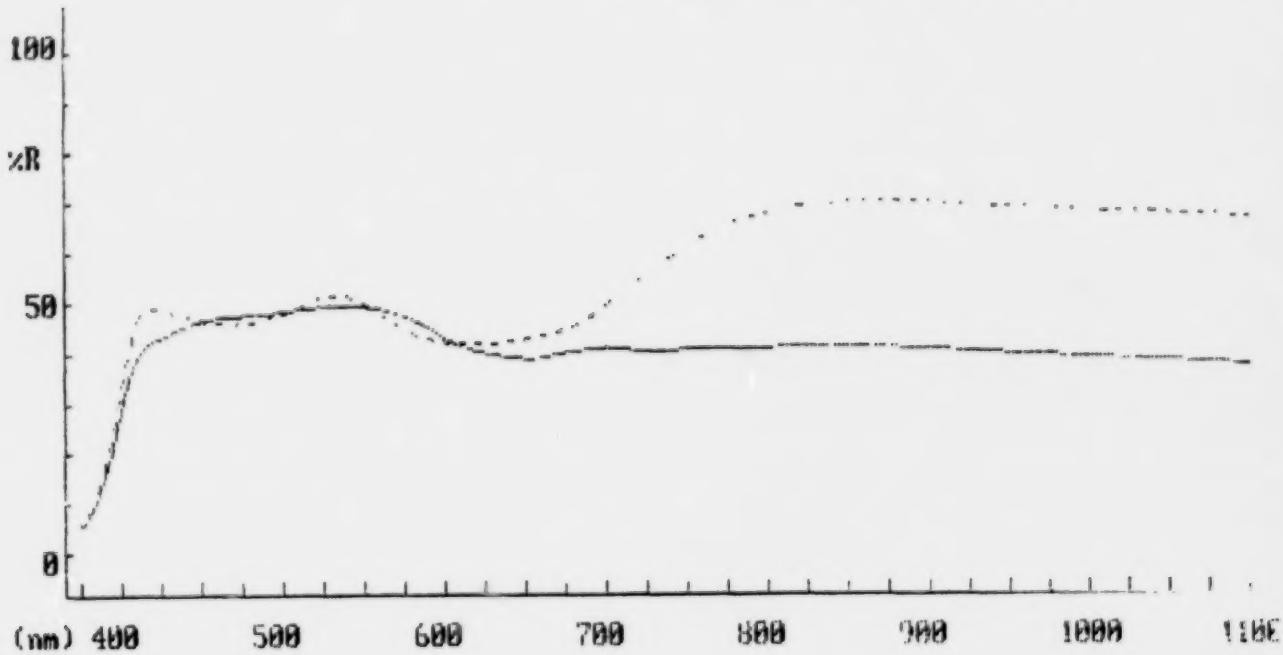
W/L	Standard	Sample	W/L	Standard	Sample
400	29.36	33.77	710	41.92	52.90
410	39.92	46.90	720	41.47	55.43
420	43.47	49.96	730	41.21	57.72
430	44.93	49.18	740	41.46	59.90
440	46.34	48.18	750	41.91	62.27
450	47.45	47.43	760	42.07	63.98
460	47.99	47.00	770	42.04	65.55
470	48.33	46.86	780	41.91	66.85
480	48.54	47.08	790	41.88	67.89
490	48.80	47.80	800	42.08	68.74
500	49.18	48.74	810	42.33	69.45
510	49.59	49.90	820	42.51	70.00
520	49.96	51.57	830	42.59	70.40
530	50.23	52.54	840	42.62	70.71
540	50.29	52.14	850	42.57	70.91
550	50.03	50.70	860	42.48	71.02
560	49.48	48.68	870	42.33	71.04
570	48.69	46.59	880	42.19	71.02
580	47.58	45.01	890	42.02	70.94
590	45.99	43.95	900	41.86	70.84
600	44.06	43.22	910	41.72	70.70
610	42.41	42.76	920	41.56	70.54
620	41.43	42.75	930	41.39	70.40
630	40.84	43.03	940	41.24	70.24
640	40.40	43.41	950	41.09	70.09
650	40.05	43.77	960	40.94	69.92
660	40.24	44.34	970	40.79	69.76
670	40.90	45.15	980	40.65	69.59
680	41.47	46.28	990	40.48	69.44
690	41.95	48.01	1000	40.33	69.28
700	42.21	50.33	1010	40.19	69.16

W/L	Standard	Sample	W/L	Standard	Sample
1020	40.05	69.05	1070	39.49	68.62
1030	39.91	68.93	1080	39.29	68.39
1040	39.77	68.84	1090	39.05	68.15
1050	39.65	68.75	1100	38.97	68.02
1060	39.58	68.70			

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD General Marine s

- - - - - - - LAST SAMPLE 7222-55 Ferro



Appendix H

Colour Formulations

(3 pages)

1-GP-61, 501-109 Matches

(Pigment names refer to dispersion formulas in Appendix C)

Clear Base	
Aroplaz 2502-ML-60	84.243
Xylene	15.164
NeoCem 250	0.147
DriRx	0.147
12% cobalt	0.152
Exkin #2	0.147
	100.000

White Base	
Aroplaz 2502-ML-60	58.353
Kronos 2102	35.012
Xylene	6.224
NeoCem 250	0.102
DriRx	0.102
12% cobalt	0.105
Exkin #2	0.102
	100.000

7222-55	
Clear Base	27.79
White Base	63.31
Ferro V12600	3.59
Ferro V11674	2.78
Ferro V700	2.53
	100.00

7222-57	
Clear Base	26.24
White Base	69.36
Ferro V12600	2.08
Ferro V11674	0.92
BASF L0086	1.39
	100.00

7222-68	
Clear Base	26.96
White Base	55.76
Shepherd A8151	9.46
Shepherd 195	1.35
Shepherd 179	6.47
	100.00

7222-80	
Clear Base	24.51
White Base	64.73
Shepherd 179	3.27
Ferro V11674	5.25
Harshaw 9885	2.25
	100.00

7222-82	
Clear Base	28.66
White Base	58.72
Shepherd 4	4.36
Shepherd 179	3.62
Shepherd 376	2.01
Shepherd 195	2.62
	100.00

7222-87	
Clear Base	26.53
White Base	70.76
Ciba 10405	2.39
Ciba 10406	0.21
Bayer 130M	0.12
	100.00

1-GP-200, 501-302 Matches

(Pigment names refer to dispersion formulas in Appendix C)

Clear Base	
Desmophen A 160	85.967
Xylene	14.033
	100.000
White Base	
Desmophen A 160	63.158
Kronos 2102	26.316
Xylene	10.526
	100.000
7222-123	
Clear Base	46.26
White Base	4.89
BASF L0084	1.90
Shepherd 123	20.01
Talc	8.00
PE Fibre	1.45
Desmodur E 3265	17.48
	100.00
Glass	58.30
	158.30

7222-126	
Clear Base	38.46
White Base	4.35
Ferro V700	8.64
Ferro V9238	1.56
Talc	19.60
PE Fibre	1.40
Desmodur E 3265	13.17
Xylene	12.82
	100.00
Glass	58.30
	158.30

1-GP-200, 503-305 Matches

(Pigment names refer to dispersion formulas in Appendix C)

Clear Base	
Desmophen A 160	85.967
Xylene	14.033
	100.000

White Base	
Desmophen A 160	63.158
Kronos 2102	26.316
Xylene	10.526
	100.000

7222-122	
Clear Base	21.11
White Base	1.75
BASF L0084	4.19
Harcros 6099	8.26
Ferro V9238	3.00
Huls C844-2862	1.18
Talc	44.82
PE Fibre	2.83
Desmodur E 3265	12.86
	100.00
Glass	58.30
	158.30

7222-124	
Clear Base	27.81
White Base	0.92
Shepherd 179	8.25
Harcros 6099	2.66
Talc	44.55
PE Fibre	2.82
Desmodur E 3265	13.00
	100.00
Glass	58.30
	158.30

7222-125	
Clear Base	29.30
White Base	0.35
Ferro V12600	2.77
Ferro V11692	5.13
Ferro V9238	1.70
Ferro V700	0.87
Talc	43.93
PE Fibre	2.87
Desmodur E 3265	13.09
	100.00
Glass	58.30
	158.30

7222-127	
Clear Base	28.93
White Base	2.71
Ciba 3RLTN	0.61
Ciba 10342	3.58
Ciba 10333	1.76
Ciba GLN	1.81
Bayer 3910	0.10
Talc	43.91
PE Fibre	2.84
Desmodur E 3265	13.76
	100.00
Glass	58.30
	158.30

Appendix I

Reflectance and Colour Data for Individual Colour Matches

(32 pages)

Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09
16:29 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: General Marine std
SAMPLE NAME: 7222-57
10 DEGREE D65

	STD	SAM
L*	74.75	74.43
a*	-6.07	-6.07
b*	1.20	-0.16

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, EQ. RED, AND BLUER

DE*	DC*	DH*
1.39	-0.12	1.35

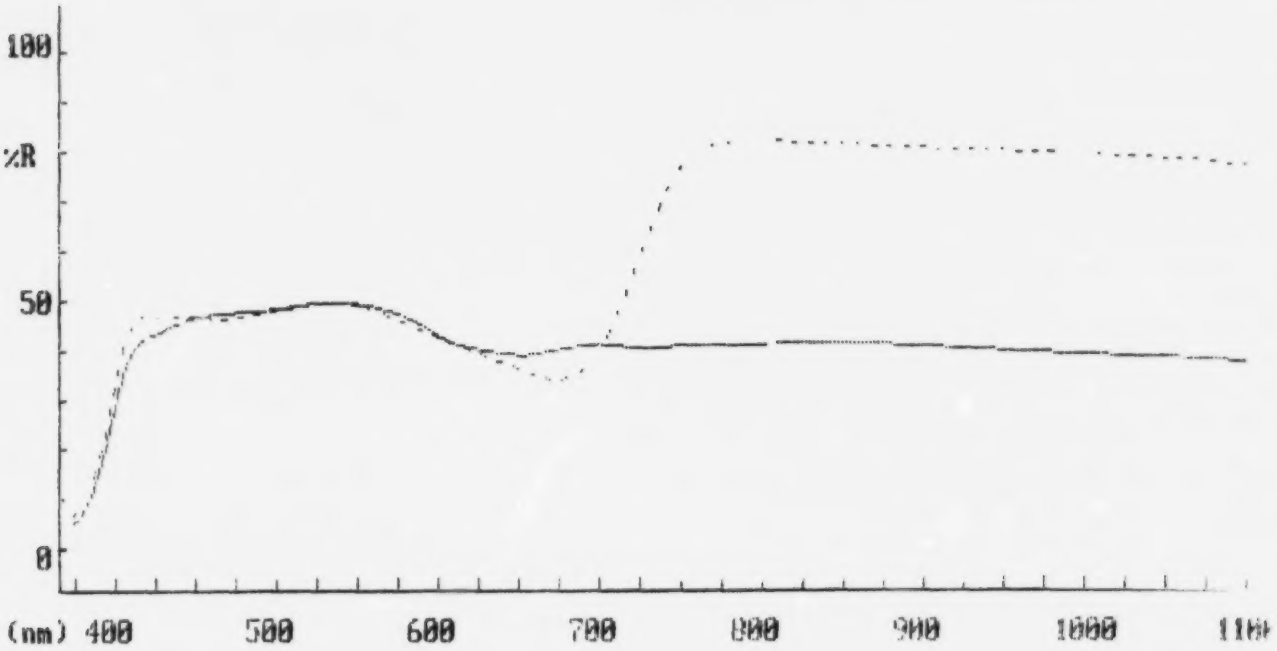
W/L	Standard	Sample	W/L	Standard	Sample
400	29.36	33.70	710	41.92	46.90
410	39.92	45.28	720	41.47	54.99
420	43.47	47.97	730	41.21	63.59
430	44.93	47.78	740	41.46	71.17
440	46.34	47.58	750	41.91	77.05
450	47.45	47.52	760	42.07	79.83
460	47.99	47.39	770	42.04	81.37
470	48.33	47.35	780	41.91	82.03
480	48.54	47.69	790	41.88	82.22
490	48.80	48.28	800	42.08	82.26
500	49.18	48.84	810	42.33	82.30
510	49.59	49.42	820	42.51	82.26
520	49.96	50.08	830	42.59	82.18
530	50.23	50.40	840	42.62	82.09
540	50.29	50.22	850	42.57	81.98
550	50.03	49.68	860	42.48	81.85
560	49.48	48.83	870	42.33	81.72
570	48.69	47.64	880	42.19	81.60
580	47.58	46.33	890	42.02	81.47
590	45.99	44.96	900	41.86	81.33
600	44.06	43.56	910	41.72	81.19
610	42.41	42.22	920	41.56	81.05
620	41.43	41.05	930	41.39	80.93
630	40.84	39.87	940	41.24	80.83
640	40.40	38.63	950	41.09	80.73
650	40.05	37.28	960	40.94	80.58
660	40.24	36.11	970	40.79	80.42
670	40.90	35.33	980	40.65	80.25
680	41.47	35.53	990	40.48	80.08
690	41.95	37.05	1000	40.33	79.90
700	42.21	40.76	1010	40.19	79.74

W/L	Standard	Sample	W/L	Standard	Sample
1020	40.05	79.58	1070	39.49	78.65
1030	39.91	79.37	1080	39.29	78.35
1040	39.77	79.21	1090	39.05	77.99
1050	39.65	79.03	1100	38.97	77.69
1060	39.58	78.85			

Data file:DND RSEX/UUL OFF/UUF OUT/LGU

——— SAMPLE General Marine s

- - - - - - - LAST SAMPLE 7222-57 UUUU



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan Specware, Version 1.09

16:31 14 Dec 98
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: General Marine std
SAMPLE NAME: 7222-68
10 DEGREE D65

	STD	SAM
L*	74.75	74.92
a*	-6.07	-8.25
b*	1.20	1.33

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS LIGHTER, GREENER, AND LESS BLUE

DE*	DC*	DH*
2.18	2.16	0.24

W/L	Standard	Sample	W/L	Standard	Sample
400	29.36	30.61	710	41.92	58.94
410	39.92	40.41	720	41.47	61.62
420	43.47	43.42	730	41.21	63.41
430	44.93	44.59	740	41.46	64.55
440	46.34	45.61	750	41.91	65.52
450	47.45	46.71	760	42.07	65.97
460	47.99	47.86	770	42.04	66.39
470	48.33	49.05	780	41.91	66.76
480	48.54	50.22	790	41.88	67.11
490	48.80	51.45	800	42.08	67.44
500	49.18	52.67	810	42.33	67.78
510	49.59	53.58	820	42.51	68.03
520	49.96	53.74	830	42.59	68.24
530	50.23	52.82	840	42.62	68.40
540	50.29	50.99	850	42.57	68.53
550	50.03	48.89	860	42.48	68.61
560	49.48	47.49	870	42.33	68.67
570	48.69	45.92	880	42.19	68.71
580	47.58	44.42	890	42.02	68.72
590	45.99	43.32	900	41.86	68.70
600	44.06	42.81	910	41.72	68.68
610	42.41	42.67	920	41.56	68.64
620	41.43	42.48	930	41.39	68.57
630	40.84	42.16	940	41.24	68.53
640	40.40	42.16	950	41.09	68.45
650	40.05	42.79	960	40.94	68.34
660	40.24	44.30	970	40.79	68.22
670	40.90	46.52	980	40.65	68.06
680	41.47	49.21	990	40.48	67.87
690	41.95	52.18	1000	40.33	67.68
700	42.21	55.53	1010	40.19	67.46

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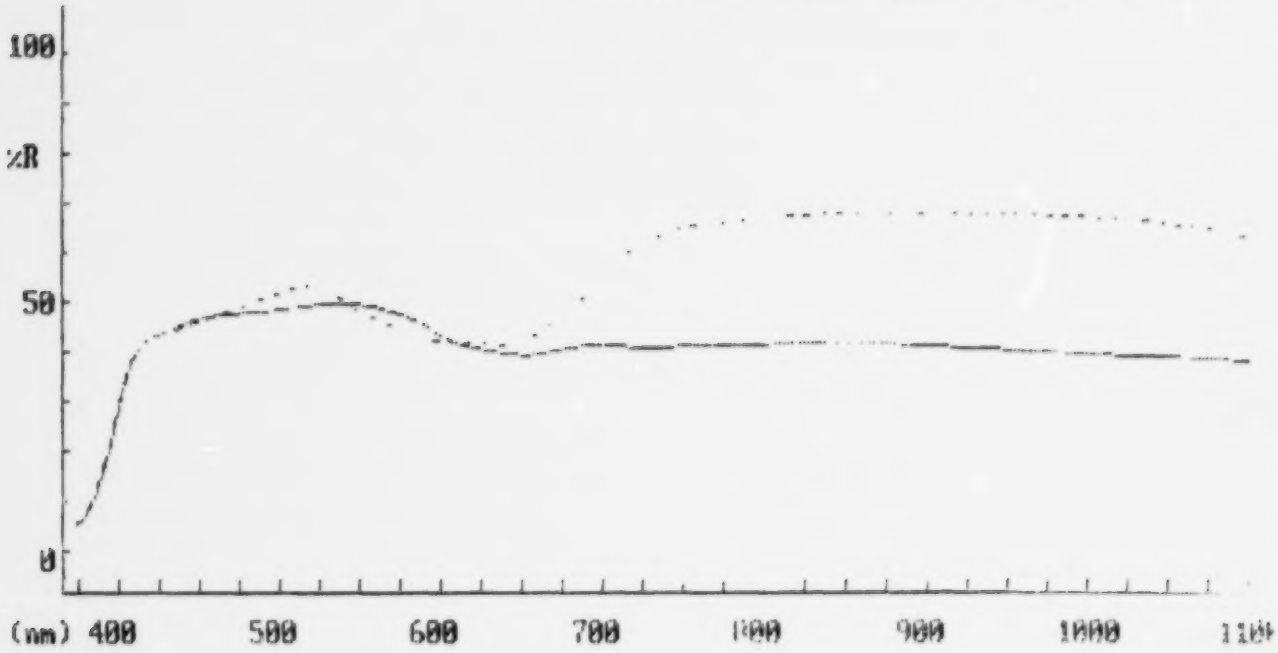
W/L	Standard	Sample	W/L	Standard	Sample
1020	40.05	67.22	1070	39.49	65.48
1030	39.91	66.92	1080	39.29	64.91
1040	39.77	66.62	1090	39.05	64.20
1050	39.65	66.27	1100	38.97	63.49
1060	39.58	65.93			

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD General Marine s

- - - - - - LAST SAMPLE 7222-68 Shep Pig



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09
16:33 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: General Marine std
SAMPLE NAME: 96-J23-7222-80
10 DEGREE D65

	STD	SAM
L*	74.75	72.86
a*	-6.07	-5.38
b*	1.20	1.26

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, LESS GREEN, AND LESS BLUE

DE*	DC*	DH*
2.02	-0.66	-0.21

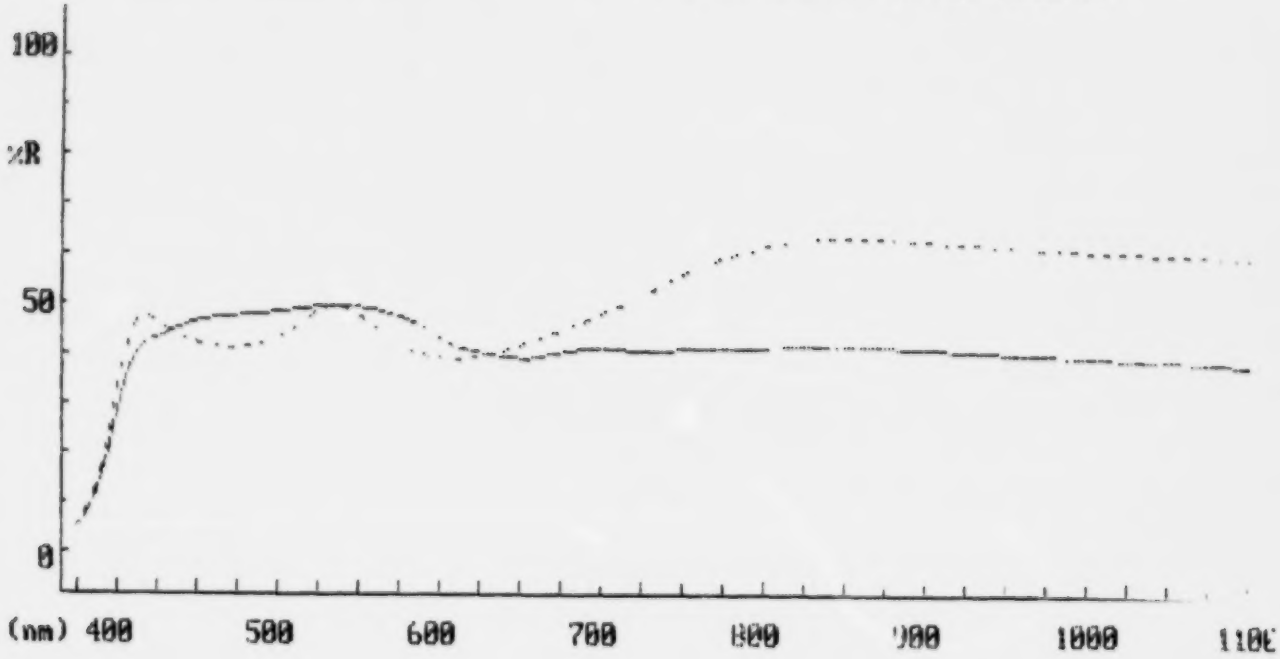
W/L	Standard	Sample	W/L	Standard	Sample
400	29.36	33.38	710	41.92	50.16
410	39.92	46.02	720	41.47	51.63
420	43.47	47.93	730	41.21	53.24
430	44.93	46.11	740	41.46	54.88
440	46.34	44.34	750	41.91	56.68
450	47.45	43.15	760	42.07	57.98
460	47.99	42.41	770	42.04	59.19
470	48.33	42.15	780	41.91	60.23
480	48.54	42.32	790	41.88	61.17
490	48.80	43.16	800	42.08	61.99
500	49.18	44.32	810	42.33	62.67
510	49.59	45.85	820	42.51	63.18
520	49.96	48.32	830	42.59	63.50
530	50.23	50.04	840	42.62	63.71
540	50.29	49.94	850	42.57	63.78
550	50.03	48.37	860	42.48	63.76
560	49.48	46.10	870	42.33	63.67
570	48.69	43.78	880	42.19	63.53
580	47.58	41.92	890	42.02	63.37
590	45.99	40.74	900	41.86	63.19
600	44.06	40.16	910	41.72	63.00
610	42.41	40.03	920	41.56	62.80
620	41.43	40.33	930	41.39	62.61
630	40.84	40.88	940	41.24	62.43
640	40.40	41.64	950	41.09	62.28
650	40.05	42.51	960	40.94	62.09
660	40.24	43.68	970	40.79	61.93
670	40.90	44.94	980	40.65	61.75
680	41.47	46.08	990	40.48	61.59
690	41.95	47.41	1000	40.33	61.44
700	42.21	48.81	1010	40.19	61.31

W/L	Standard	Sample	W/L	Standard	Sample
1020	40.05	61.17	1070	39.49	60.57
1030	39.91	61.04	1080	39.29	60.34
1040	39.77	60.92	1090	39.05	60.09
1050	39.65	60.81	1100	38.97	60.03
1060	39.58	60.70			

Data file:DND INSEX/1UL OFT/UUF CUT/LAU

——— STANDARD General Marine s

·· ··· LAST SAMPLE 96-J23-7222-GB



P516888.PDF [Page: 147 of 183]

Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

16:34 16:Dec:96
RSEX/UVL OFF/UVF OUT/LAR

STANDARD NAME: General Marine std
SAMPLE NAME: 96-J23-7222-82
10 DEGREE D65

	STD	SAM
L*	74.75	75.21
a*	-6.07	-7.37
b*	1.20	1.17

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS LIGHTER, GREENER, AND EQ. BLUE

DE*	DC*	DH*
1.37	1.27	0.25

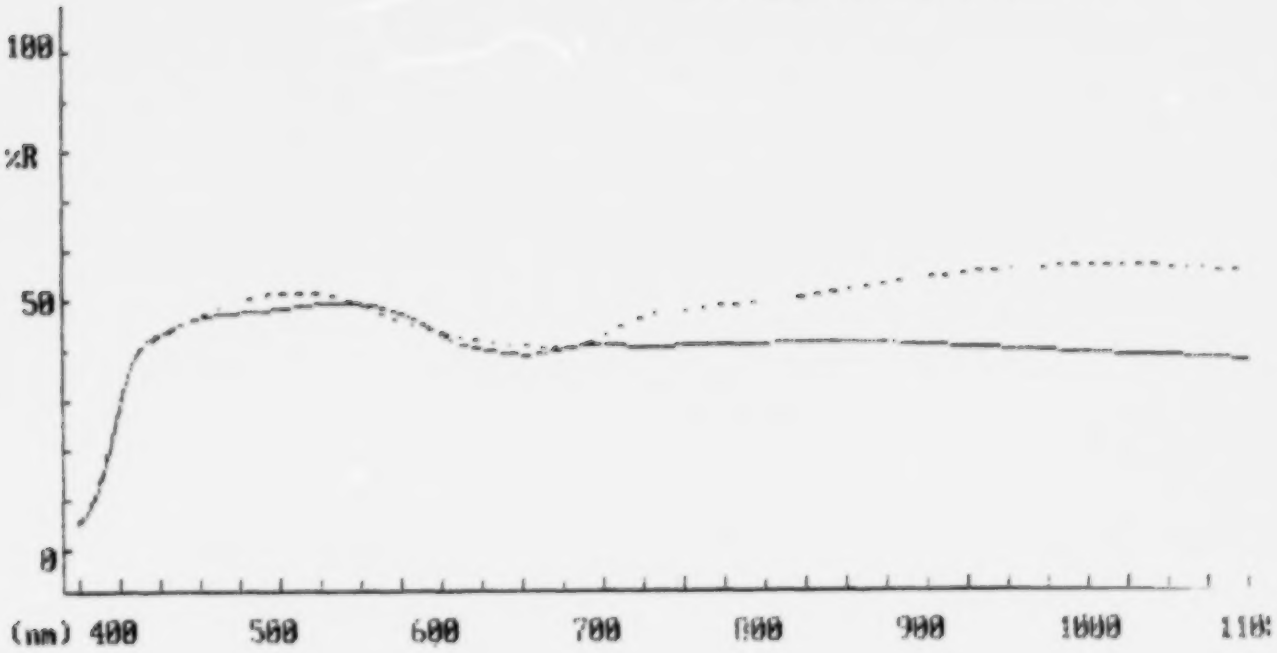
W/L	Standard	Sample	W/L	Standard	Sample
400	29.36	30.30	710	41.92	45.39
410	39.92	39.59	720	41.47	46.79
420	43.47	42.81	730	41.21	47.78
430	44.93	44.41	740	41.46	48.36
440	46.34	46.07	750	41.91	48.85
450	47.45	47.71	760	42.07	49.19
460	47.99	49.13	770	42.04	49.48
470	48.33	50.35	780	41.91	49.77
480	48.54	51.27	790	41.88	50.09
490	48.80	51.94	800	42.08	50.46
500	49.18	52.34	810	42.33	50.86
510	49.59	52.51	820	42.51	51.31
520	49.96	52.38	830	42.59	51.78
530	50.23	51.89	840	42.62	52.28
540	50.29	51.05	850	42.57	52.79
550	50.03	49.97	860	42.48	53.32
560	49.48	48.59	870	42.33	53.82
570	48.69	47.16	880	42.19	54.31
580	47.58	46.12	890	42.02	54.75
590	45.99	45.35	900	41.86	55.20
600	44.06	44.48	910	41.72	55.60
610	42.41	43.56	920	41.56	55.96
620	41.43	42.86	930	41.39	56.28
630	40.84	42.50	940	41.24	56.58
640	40.40	42.23	950	41.09	56.85
650	40.05	41.87	960	40.94	57.06
660	40.24	41.33	970	40.79	57.22
670	40.90	41.20	980	40.65	57.35
680	41.47	41.28	990	40.48	57.42
690	41.95	42.21	1000	40.33	57.48
700	42.21	43.60	1010	40.19	57.50

W/L	Standard	Sample	W/L	Standard	Sample
1020	40.05	57.49	1070	39.49	57.00
1030	39.91	57.42	1080	39.29	56.69
1040	39.77	57.36	1090	39.05	56.34
1050	39.65	57.27	1100	38.97	56.28
1060	39.58	57.18			

Data file:DMD RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD General Marine s

..... LAST SAMPLE 96-J23-7222-82



STANDARD NAME: General Marine std
SAMPLE NAME: 96-J23-7222-87
10 DEGREE D65

	STD	SAM
L*	74.75	72.92
a*	-6.07	-6.15
b*	1.20	1.87

DELTA DESCRIPTOR - RECTANGULAR

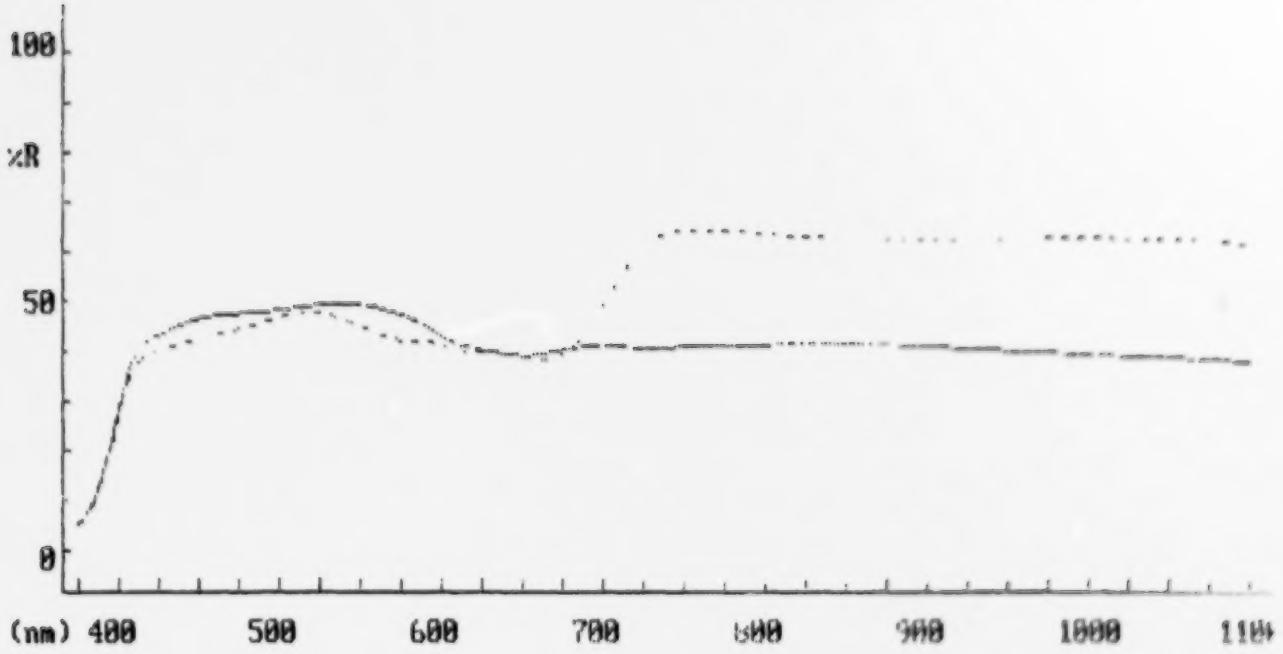
CIELab THE SAMPLE IS DARKER, GREENER, AND LESS BLUE

DE*	DC*	DH*
1.95	0.24	-0.63

W/L	Standard	Sample	W/L	Standard	Sample
400	29.36	28.43	710	41.92	55.32
410	39.92	37.72	720	41.47	60.01
420	43.47	40.59	730	41.21	62.84
430	44.93	41.63	740	41.46	64.29
440	46.34	42.53	750	41.91	64.92
450	47.45	43.37	760	42.07	64.98
460	47.99	44.18	770	42.04	64.95
470	48.33	45.04	780	41.91	64.79
480	48.54	45.90	790	41.88	64.55
490	48.80	46.82	800	42.08	64.28
500	49.18	47.68	810	42.33	64.07
510	49.59	48.41	820	42.51	63.84
520	49.96	48.65	830	42.59	63.63
530	50.23	48.23	840	42.62	63.46
540	50.29	47.24	850	42.57	63.31
550	50.03	45.96	860	42.48	63.19
560	49.48	44.55	870	42.33	63.11
570	48.69	43.41	880	42.19	63.08
580	47.58	43.15	890	42.02	63.06
590	45.99	42.99	900	41.86	63.08
600	44.06	42.10	910	41.72	63.11
610	42.41	41.00	920	41.56	63.15
620	41.43	40.63	930	41.39	63.22
630	40.84	40.71	940	41.24	63.31
640	40.40	40.54	950	41.09	63.42
650	40.05	39.98	960	40.94	63.49
660	40.24	39.48	970	40.79	63.53
670	40.90	39.79	980	40.65	63.56
680	41.47	41.38	990	40.48	63.56
690	41.95	44.75	1000	[illegible]	63.57
700	42.21	49.74	1010	[illegible]	63.55

W/L	Standard	Sample	W/L	Standard	Sample
1020	40.05	63.51	1070	39.49	63.11
1030	39.91	63.45	1080	39.29	62.84
1040	39.77	63.39	1090	39.05	62.47
1050	39.65	63.33	1100	38.97	62.20
1060	39.58	63.25			

Data file DND [illegible]



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

14:14 9:Jan:97
RSEX/UVL OFF [illegible]

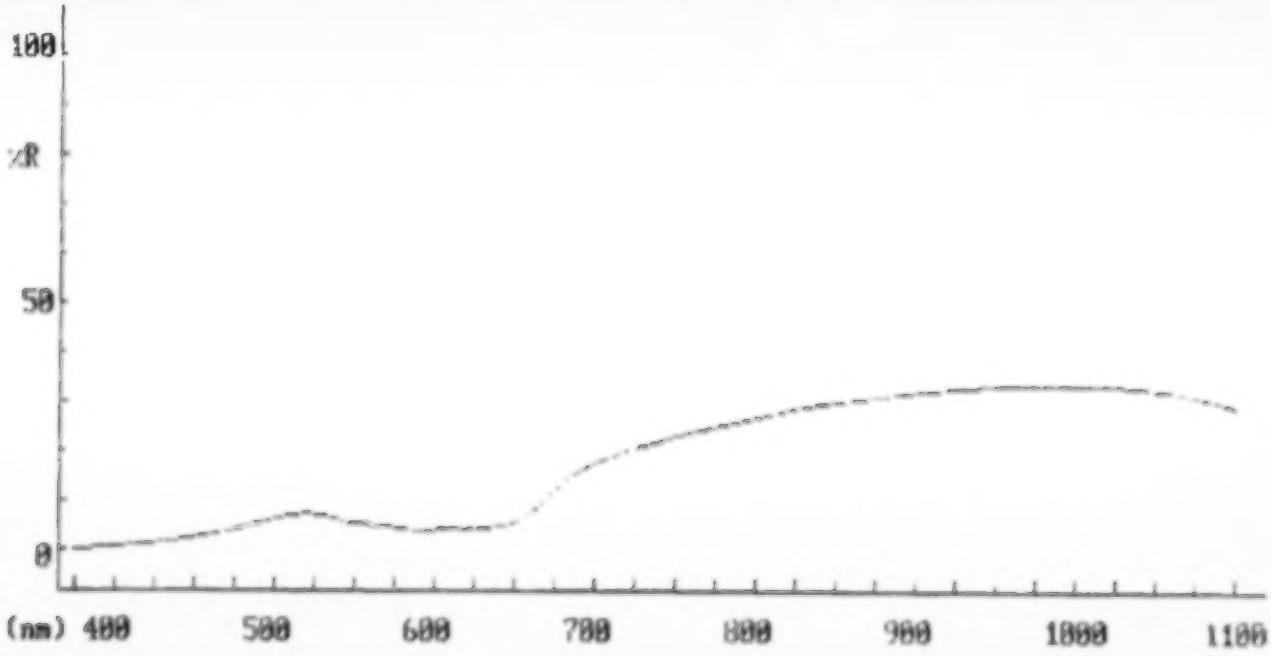
STANDARD NAME: Shep. A8151 grey Masstone
SAMPLE NAME:
10 DEGREE D65

	STD
L*	30.56
a*	-9.96
b*	11.84

W/L	Standard
380	1.53
390	1.74
400	1.87
410	2.17
420	2.45
430	2.71
440	3.15
450	3.68
460	4.29
470	4.95
480	5.73
490	6.54
500	7.40
510	8.11
520	8.39
530	8.06
540	7.26
550	6.49
560	6.25
570	5.89
580	5.39
590	5.07
600	5.20
610	5.56
620	5.68
630	5.63
640	5.86
650	6.71
660	8.53
670	11.49
680	14.60
690	16.93
700	18.57
710	19.88
720	21.05
730	22.07
740	22.94
750	24.08
760	24.88
770	25.56
780	26.28
790	27.02
800	27.81
810	28.58
820	29.26
830	29.90
840	30.44
850	30.94
860	31.40
870	31.80
880	32.18
890	32.53
900	32.85
910	33.16
920	33.41
930	33.65
940	33.86
950	34.04
960	34.16
970	34.25
980	34.31
990	34.31
1000	34.30
1010	34.20
1020	34.06
1030	33.85
1040	33.57
1050	33.24
1060	32.85
1070	32.29
1080	31.58
1090	30.76
1100	30.00

Data file.DND RSEX/UVL OFF/UVF OUT/LAU

——— STANDARD Shep. A8151 grey



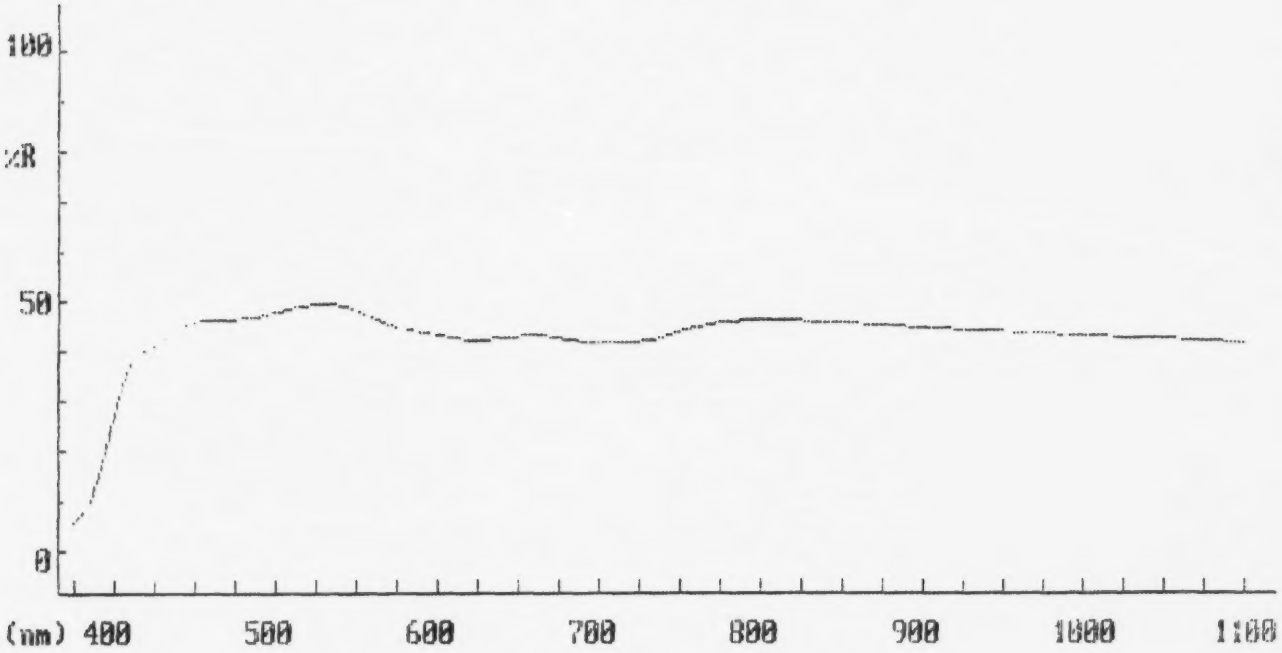
STANDARD NAME: Matchless 501-109 std.
SAMPLE NAME:
10 DEGREE D65

	STD
L*	74.33
a*	-5.42
b*	1.78

W/L	Standard	W/L	Standard
380	8.84	750	44.69
390	15.84	760	45.50
400	28.10	770	46.23
410	37.82	780	46.69
420	41.24	790	46.93
430	43.03	800	47.03
440	45.08	810	47.03
450	46.64	820	46.96
460	47.13	830	46.84
470	47.33	840	46.71
480	47.50	850	46.55
490	47.91	860	46.38
500	48.62	870	46.20
510	49.37	880	46.01
520	49.96	890	45.82
530	50.19	900	45.65
540	49.89	910	45.47
550	48.95	920	45.29
560	47.53	930	45.11
570	46.20	940	44.95
580	45.28	950	44.81
590	44.62	960	44.64
600	43.99	970	44.48
610	43.43	980	44.32
620	43.10	990	44.16
630	43.12	1000	44.01
640	43.45	1010	43.85
650	43.70	1020	43.70
660	43.86	1030	43.55
670	43.67	1040	43.41
680	43.08	1050	43.30
690	42.59	1060	43.21
700	42.27	1070	43.12
710	42.29	1080	42.92
720	42.56	1090	42.65
730	42.91	1100	42.51
740	43.60		

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

STANDARD Matchless 501-10



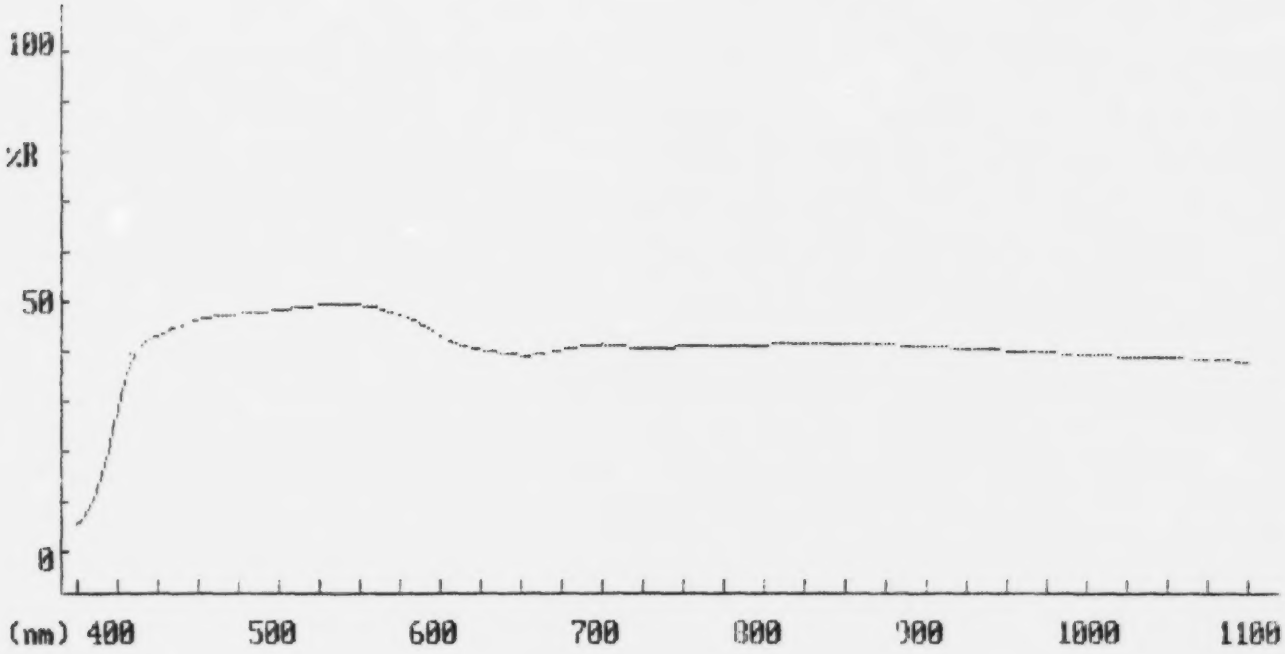
STANDARD NAME: General Marine std
SAMPLE NAME:
10 DEGREE D65

	STD
L*	74.75
a*	-6.07
b*	1.20

W/L	Standard	W/L	Standard
380	8.66	750	41.91
390	16.17	760	42.07
400	29.36	770	42.04
410	39.92	780	41.91
420	43.47	790	41.88
430	44.93	800	42.08
440	46.34	810	42.33
450	47.45	820	42.51
460	47.99	830	42.59
470	48.33	840	42.62
480	48.54	850	42.57
490	48.80	860	42.48
500	49.18	870	42.33
510	49.59	880	42.19
520	49.96	890	42.02
530	50.23	900	41.86
540	50.29	910	41.72
550	50.03	920	41.56
560	49.48	930	41.39
570	48.69	940	41.24
580	47.58	950	41.09
590	45.99	960	40.94
600	44.06	970	40.79
610	42.41	980	40.65
620	41.43	990	40.48
630	40.84	1000	40.33
640	40.40	1010	40.19
650	40.05	1020	40.05
660	40.24	1030	39.91
670	40.90	1040	39.77
680	41.47	1050	39.65
690	41.95	1060	39.58
700	42.21	1070	39.49
710	41.92	1080	39.29
720	41.47	1090	39.05
730	41.21	1100	38.97
740	41.46		

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD General Marine s



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09
15:48 14:Jan:97
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Tibbetts 501-302 std
SAMPLE NAME:
10 DEGREE D65

	STD
L*	35.24
a*	-0.31
b*	-2.31

W/L	Standard	W/L	Standard
380	7.69	750	7.89
390	8.72	760	7.85
400	9.47	770	7.85
410	9.69	780	7.84
420	9.61	790	7.82
430	9.52	800	7.81
440	9.42	810	7.81
450	9.33	820	7.79
460	9.23	830	7.79
470	9.14	840	7.78
480	9.05	850	7.78
490	8.98	860	7.78
500	8.92	870	7.77
510	8.85	880	7.77
520	8.78	890	7.77
530	8.72	900	7.78
540	8.66	910	7.79
550	8.60	920	7.79
560	8.54	930	7.79
570	8.47	940	7.80
580	8.45	950	7.81
590	8.38	960	7.82
600	8.34	970	7.83
610	8.32	980	7.84
620	8.24	990	7.85
630	8.22	1000	7.86
640	8.15	1010	7.87
650	8.16	1020	7.88
660	8.08	1030	7.89
670	8.06	1040	7.90
680	8.08	1050	7.93
690	7.99	1060	7.93
700	8.02	1070	7.95
710	7.97	1080	7.90
720	7.95	1090	7.87
730	7.91	1100	7.95
740	7.89		

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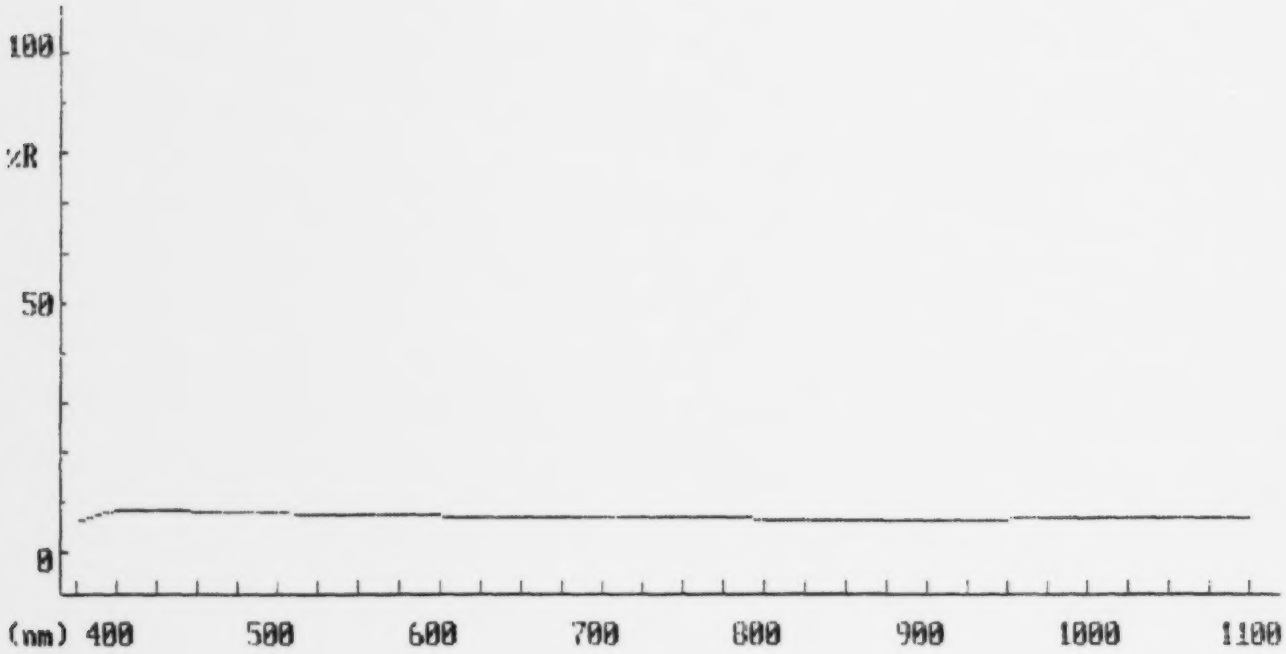
Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Tibbetts 501-302



Report # 97rJ2382204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09

15:50 14:Jar
RSEX/UVL OFF/UVF OUT/

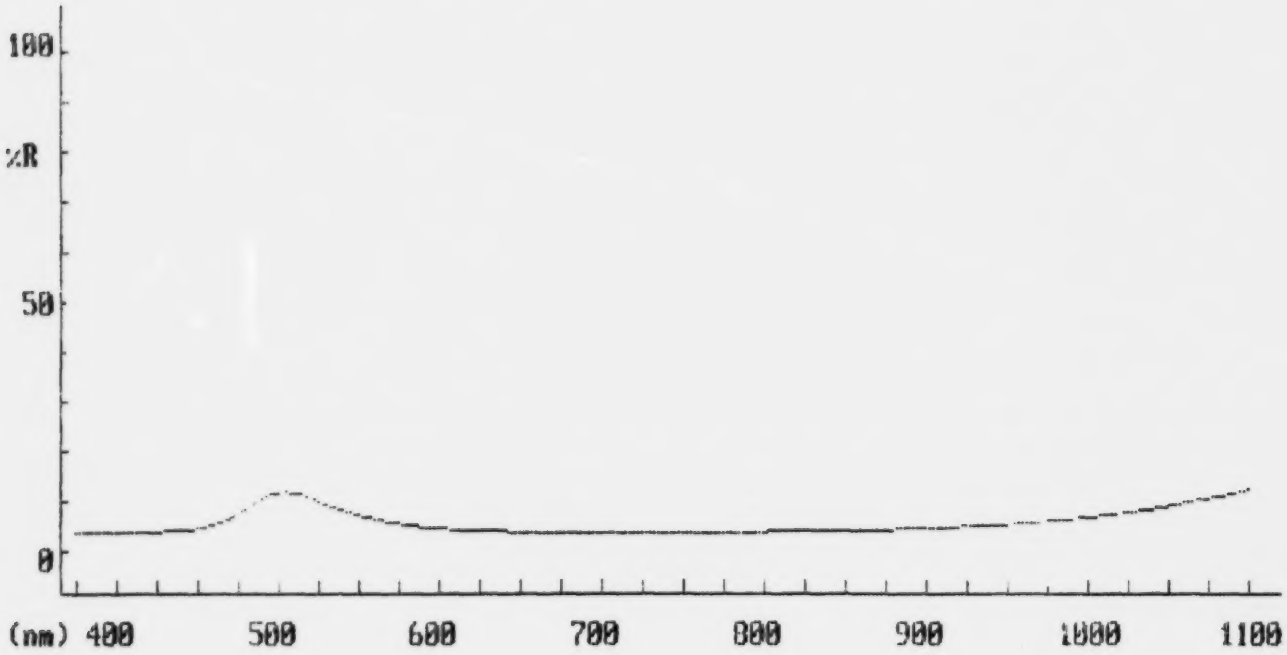
STANDARD NAME: Tibbetts 503-305 std
SAMPLE NAME:
10 DEGREE D65

	STD
L*	35.03
a*	-18.38
b*	6.51

W/L	Standard	W/L	Standard
380	4.97	750	5.08
390	4.96	760	5.10
400	4.95	770	5.14
410	5.00	780	5.15
420	5.06	790	5.17
430	5.23	800	5.20
440	5.43	810	5.25
450	5.83	820	5.31
460	6.59	830	5.34
470	7.97	840	5.41
480	9.97	850	5.49
490	11.95	860	5.56
500	13.00	870	5.64
510	12.85	880	5.74
520	11.85	890	5.84
530	10.61	900	5.95
540	9.45	910	6.08
550	8.46	920	6.23
560	7.67	930	6.38
570	7.06	940	6.56
580	6.57	950	6.75
590	6.18	960	6.97
600	5.88	970	7.23
610	5.63	980	7.49
620	5.48	990	7.79
630	5.31	1000	8.12
640	5.23	1010	8.49
650	5.13	1020	8.91
660	5.13	1030	9.37
670	5.04	1040	9.88
680	4.98	1050	10.44
690	5.00	1060	11.04
700	5.05	1070	11.62
710	5.03	1080	12.20
720	5.00	1090	12.82
730	5.01	1100	13.75
740	4.98		

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Tibbetts 503-305



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09
15:55 16:Jan:97
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Tibbetts 501-302 std
SAMPLE NAME: 96-J23-7222-123
10 DEGREE D65

	STD	SAM
L*	35.24	34.36
a*	-0.31	-1.14
b*	-2.31	-2.24

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, GREENER, AND LESS BLUE

DE*	DC*	DH*
1.21	0.18	-0.80

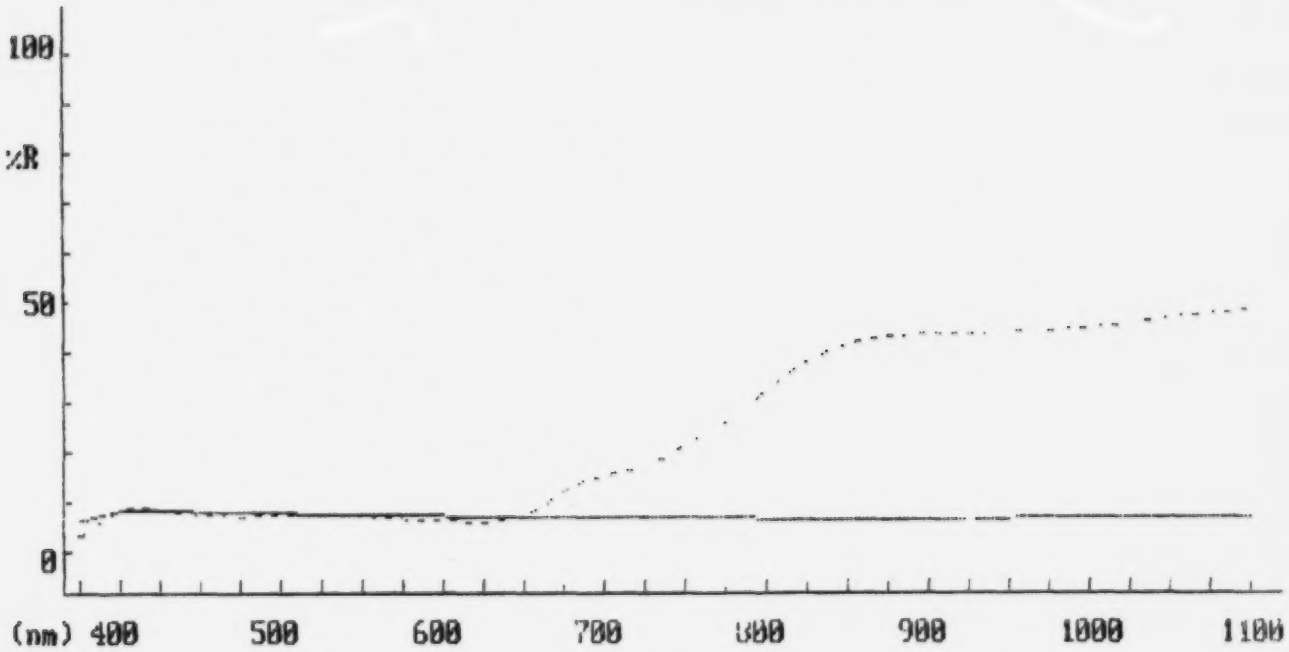
W/L	Standard	Sample	W/L	Standard	Sample
380	7.69	5.15	690	7.99	15.50
390	8.72	7.56	700	8.02	16.40
400	9.47	9.62	710	7.97	17.06
410	9.69	10.21	720	7.95	17.88
420	9.61	9.87	730	7.91	18.87
430	9.52	9.40	740	7.89	20.16
440	9.42	9.05	750	7.89	22.21
450	9.33	8.72	760	7.85	24.00
460	9.23	8.43	770	7.85	25.94
470	9.14	8.31	780	7.84	28.19
480	9.05	8.33	790	7.82	30.60
490	8.98	8.37	800	7.81	33.13
500	8.92	8.41	810	7.81	35.57
510	8.85	8.47	820	7.79	37.77
520	8.78	8.58	830	7.79	39.63
530	8.72	8.67	840	7.78	41.14
540	8.66	8.66	850	7.78	42.29
550	8.60	8.49	860	7.78	43.13
560	8.54	8.22	870	7.77	43.71
570	8.47	7.93	880	7.77	44.09
580	8.45	7.66	890	7.77	44.33
590	8.38	7.47	900	7.78	44.50
600	8.34	7.36	910	7.79	44.58
610	8.32	7.30	920	7.79	44.64
620	8.24	7.24	930	7.79	44.68
630	8.22	7.31	940	7.80	44.74
640	8.15	7.62	950	7.81	44.82
650	8.16	8.42	960	7.82	44.91
660	8.08	10.04	970	7.83	45.05
670	8.06	12.32	980	7.84	45.22
680	8.08	14.19	990	7.85	45.43

W/L	Standard	Sample	W/L	Standard	Sample
1000	7.86	45.69	1060	7.93	48.11
1010	7.87	46.00	1070	7.95	48.45
1020	7.88	46.37	1080	7.90	48.68
1030	7.89	46.75	1090	7.87	48.90
1040	7.90	47.19	1100	7.95	49.55
1050	7.93	47.65			

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Tibbetts 501-302

------ LAST SAMPLE 96-J23-7222-123



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, Version 1.09
15:57 16:Jan:9/
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Tibbetts 501-302 std
SAMPLE NAME: 96-J23-7222-126
10 DEGREE D65

	STD	SAM
L*	35.24	33.97
a*	-0.31	0.17
b*	-2.31	-3.16

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, LESS GREEN, AND BLUER

DE*	DC*	DH*
1.60	0.84	0.52

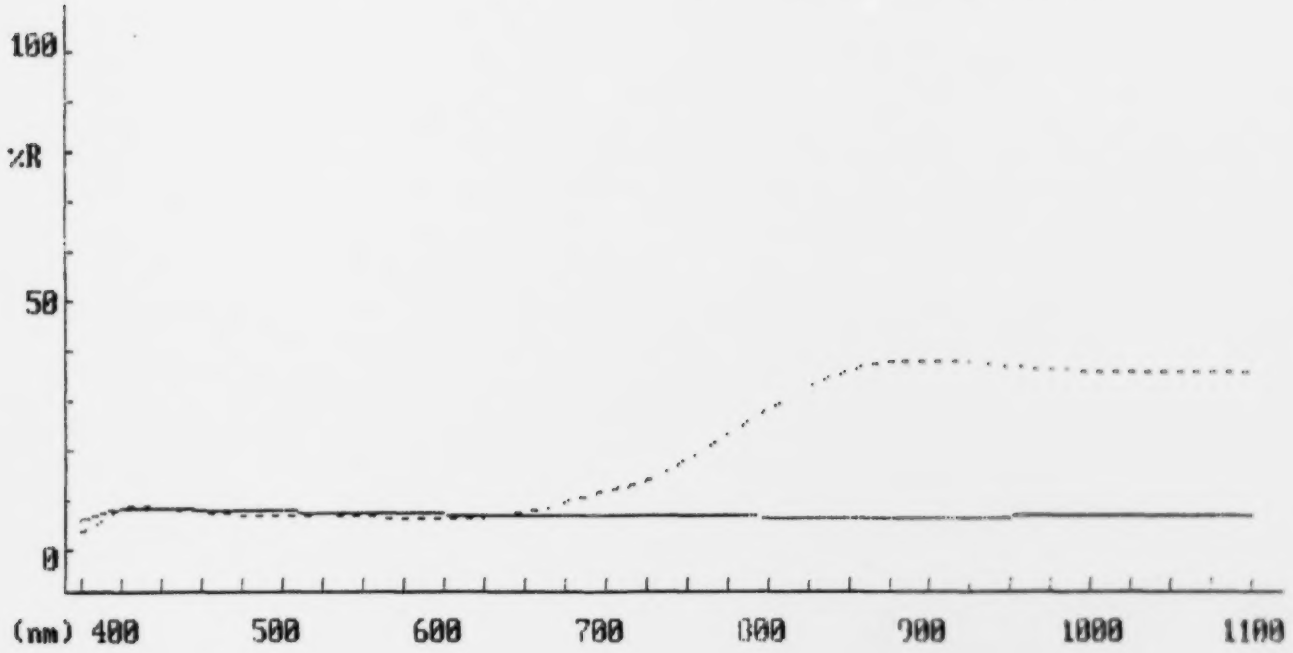
W/L	Standard	Sample	W/L	Standard	Sample
380	7.69	5.63	690	7.99	12.11
390	8.72	7.55	700	8.02	12.93
400	9.47	9.57	710	7.97	13.72
410	9.69	10.18	720	7.95	14.64
420	9.61	9.97	730	7.91	15.80
430	9.52	9.57	740	7.89	17.19
440	9.42	9.16	750	7.89	19.31
450	9.33	8.82	760	7.85	21.19
460	9.23	8.57	770	7.85	23.15
470	9.14	8.38	780	7.84	25.19
480	9.05	8.26	790	7.82	27.18
490	8.98	8.24	800	7.81	29.16
500	8.92	8.25	810	7.81	31.05
510	8.85	8.27	820	7.79	32.80
520	8.78	8.34	830	7.79	34.42
530	8.72	8.35	840	7.78	35.82
540	8.66	8.24	850	7.78	36.98
550	8.60	8.03	860	7.78	37.86
560	8.54	7.83	870	7.77	38.48
570	8.47	7.66	880	7.77	38.84
580	8.45	7.50	890	7.77	39.00
590	8.38	7.35	900	7.78	39.01
600	8.34	7.33	910	7.79	38.89
610	8.32	7.47	920	7.79	38.68
620	8.24	7.69	930	7.79	38.41
630	8.22	7.89	940	7.80	38.13
640	8.15	8.26	950	7.81	37.86
650	8.16	8.65	960	7.82	37.59
660	8.08	9.30	970	7.83	37.35
670	8.06	10.30	980	7.84	37.13
680	8.08	11.25	990	7.85	36.93

W/L	Standard	Sample	W/L	Standard	Sample
1000	7.86	36.80	1060	7.93	36.80
1010	7.87	36.70	1070	7.95	36.83
1020	7.88	36.64	1080	7.90	36.80
1030	7.89	36.63	1090	7.87	36.79
1040	7.90	36.66	1100	7.95	36.69
1050	7.93	36.72			

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Tibbetts 501-302

····· LAST SAMPLE 96-J23-7222-126



P516888.PDF [Page: 165 of 183]

Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan SpecWare, version 1.09 15:58 16:Jan:97
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Tibbetts 503-305 std
SAMPLE NAME: 96-J23-7222-122
10 DEGREE D65

	STD	SAM
L*	35.03	34.80
a*	-18.38	-17.04
b*	6.51	7.92

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, LESS GREEN, AND YELLOWER

DE*	DC*	DH*
1.96	-0.71	-1.81

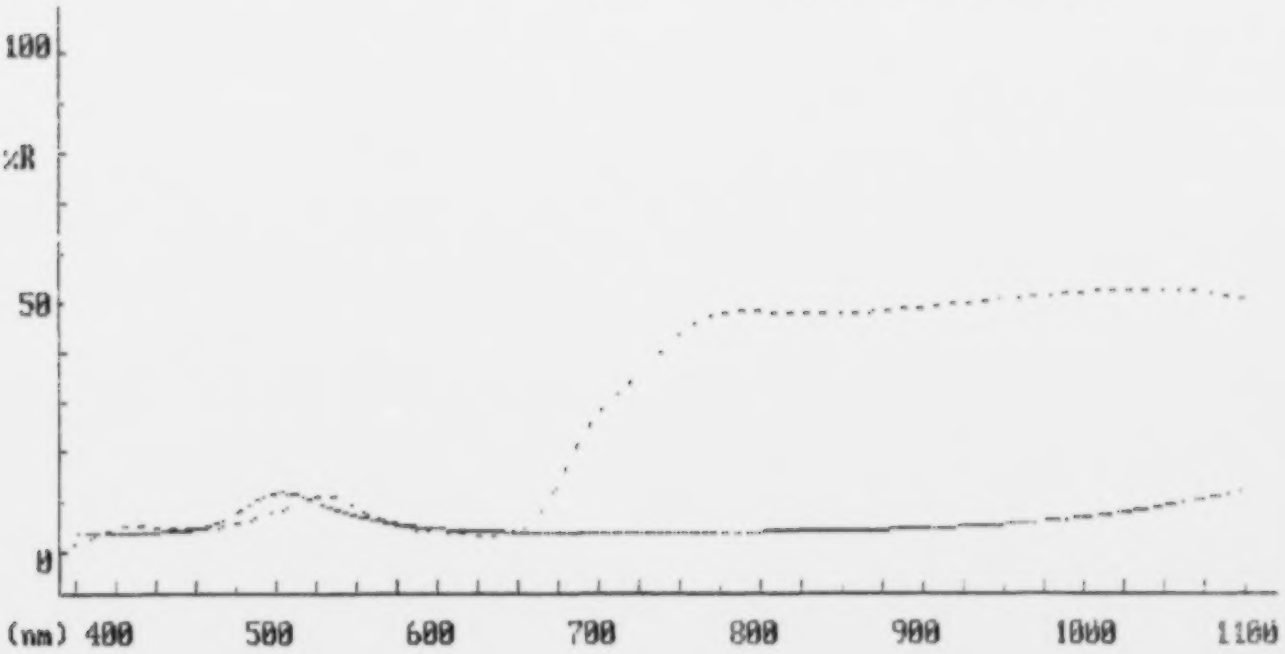
W/L	Standard	Sample	W/L	Standard	Sample
380	4.97	3.31	690	5.00	23.62
390	4.96	4.61	700	5.05	28.52
400	4.95	6.05	710	5.03	31.79
410	5.00	6.52	720	5.00	34.81
420	5.06	6.22	730	5.01	38.14
430	5.23	5.88	740	4.98	41.45
440	5.43	5.74	750	5.08	44.78
450	5.83	5.79	760	5.10	46.84
460	6.59	5.99	770	5.14	48.20
470	7.97	6.52	780	5.15	48.86
480	9.97	7.29	790	5.17	49.04
490	11.95	8.23	800	5.20	49.01
500	13.00	9.23	810	5.25	48.90
510	12.85	10.28	820	5.31	48.75
520	11.85	11.63	830	5.34	48.65
530	10.61	12.37	840	5.41	48.63
540	9.45	11.77	850	5.49	48.68
550	8.46	10.08	860	5.56	48.81
560	7.67	8.37	870	5.64	49.00
570	7.06	7.10	880	5.74	49.26
580	6.57	6.15	890	5.84	49.58
590	6.18	5.49	900	5.95	49.92
600	5.88	5.07	910	6.08	50.26
610	5.63	4.84	920	6.23	50.64
620	5.48	4.69	930	6.38	51.02
630	5.31	4.58	940	6.56	51.39
640	5.23	4.76	950	6.75	51.74
650	5.13	5.43	960	6.97	52.05
660	5.13	7.44	970	7.23	52.32
670	5.04	11.47	980	7.49	52.57
680	4.98	17.34	990	7.79	52.79

W/L	Standard	Sample	W/L	Standard	Sample
1000	8.12	53.00	1060	11.04	53.41
1010	8.49	53.17	1070	11.62	53.17
1020	8.91	53.31	1080	12.20	52.77
1030	9.37	53.40	1090	12.82	52.28
1040	9.88	53.47	1100	13.75	51.95
1050	10.44	53.46			

Data file:DND RSEX/UUL OFF/UUF OUT/LAU

——— STANDARD Tibbetts 503-305

------ LAST SAMPLE 96-123-7222-122



STANDARD NAME: Tibbetts 503-305 std
SAMPLE NAME: 96-J23-7222-124
10 DEGREE D65

	STD	SAM
L*	35.03	33.44
a*	-18.38	-18.16
b*	6.51	6.11

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, LESS GREEN, AND LESS YELLOW

DE*	DC*	DH*
1.65	-0.34	0.30

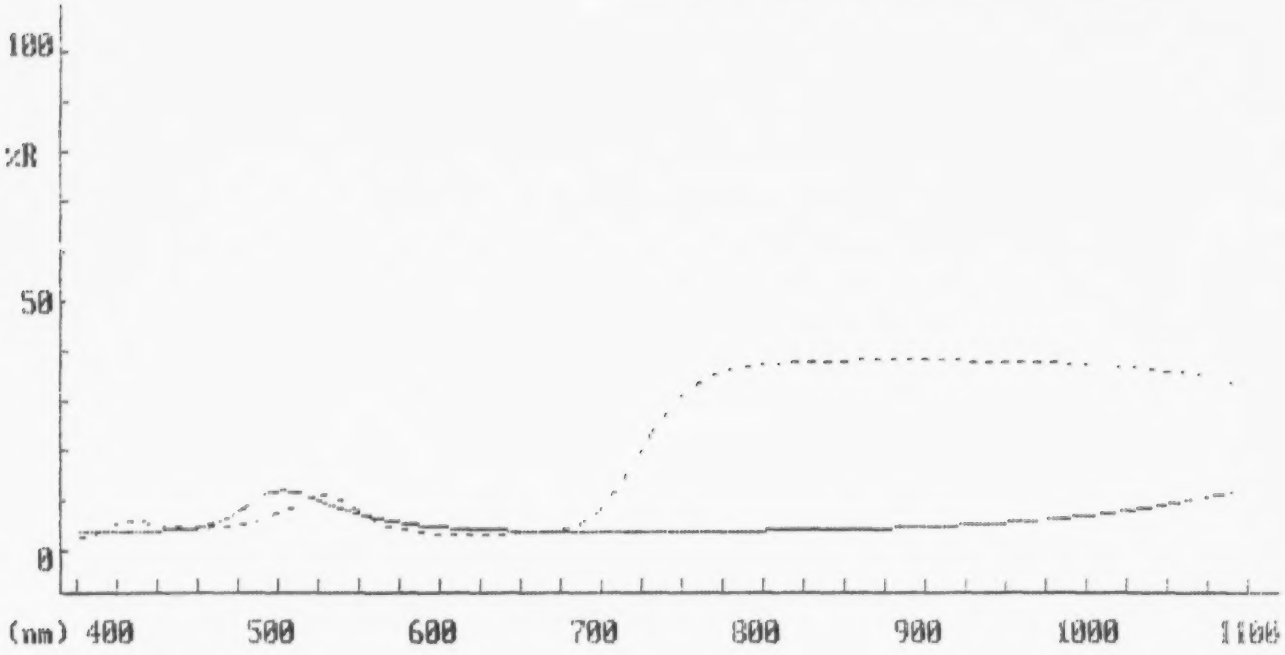
W/L	Standard	Sample	W/L	Standard	Sample
380	4.97	4.12	690	5.00	7.05
390	4.96	4.94	700	5.05	9.47
400	4.95	6.39	710	5.03	13.37
410	5.00	7.11	720	5.00	18.44
420	5.06	6.70	730	5.01	23.61
430	5.23	6.12	740	4.98	28.13
440	5.43	5.78	750	5.08	32.10
450	5.83	5.66	760	5.10	34.45
460	6.59	5.77	770	5.14	36.17
470	7.97	6.05	780	5.15	37.23
480	9.97	6.55	790	5.17	37.84
490	11.95	7.44	800	5.20	38.23
500	13.00	8.58	810	5.25	38.49
510	12.85	10.02	820	5.31	38.66
520	11.85	11.72	830	5.34	38.81
530	10.61	12.26	840	5.41	38.93
540	9.45	11.08	850	5.49	39.02
550	8.46	9.16	860	5.56	39.08
560	7.67	7.27	870	5.64	39.13
570	7.06	5.89	880	5.74	39.14
580	6.57	5.22	890	5.84	39.15
590	6.18	4.83	900	5.95	39.15
600	5.88	4.53	910	6.08	39.13
610	5.63	4.35	920	6.23	39.10
620	5.48	4.40	930	6.38	39.04
630	5.31	4.52	940	6.56	38.97
640	5.23	4.67	950	6.75	38.90
650	5.13	4.72	960	6.97	38.82
660	5.13	4.83	970	7.23	38.71
670	5.04	5.14	980	7.49	38.58
680	4.98	5.71	990	7.79	38.42

W/L	Standard	Sample	W/L	Standard	Sample
1000	8.12	38.25	1060	11.04	36.50
1010	8.49	38.06	1070	11.62	35.98
1020	8.91	37.82	1080	12.20	35.36
1030	9.37	37.56	1090	12.82	34.57
1040	9.86	37.24	1100	13.75	33.77
1050	10.44	36.89			

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Tibbetts 503-305

------ LAST SAMPLE 96-J23-7222-124



STANDARD NAME: Tibbetts 503-305 std
SAMPLE NAME: 96-J23-7222-125
10 DEGREE D65

	STD	SAM
L*	35.03	34.37
a*	-18.38	-19.35
b*	6.51	5.07

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, GREENER, AND LESS YELLOW

DE*	DC*	DH*
1.85	0.50	1.66

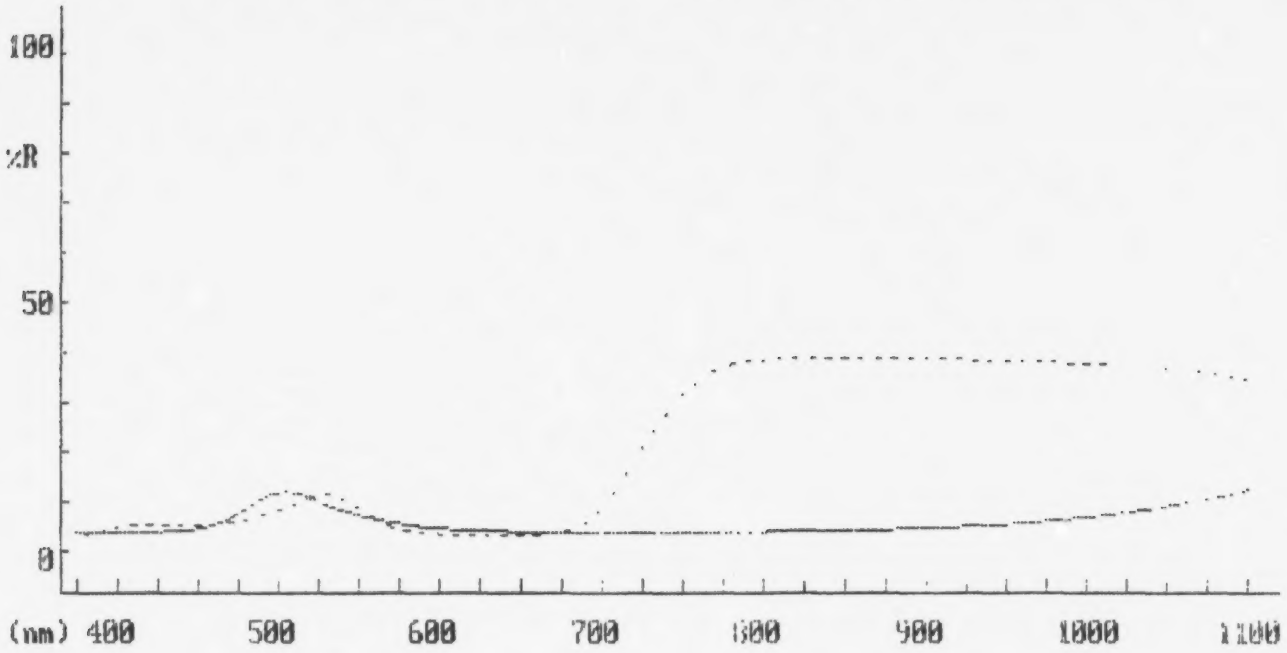
W/L	Standard	Sample	W/L	Standard	Sample
380	4.97	4.18	690	5.00	7.13
390	4.96	5.06	700	5.05	9.93
400	4.95	6.09	710	5.03	14.09
410	5.00	6.59	720	5.00	19.11
420	5.06	6.44	730	5.01	24.14
430	5.23	6.28	740	4.98	28.63
440	5.43	6.29	750	5.08	32.76
450	5.83	6.43	760	5.10	35.39
460	6.59	6.71	770	5.14	37.37
470	7.97	7.10	780	5.15	38.57
480	9.97	7.66	790	5.17	39.22
490	11.95	8.50	800	5.20	39.56
500	13.00	9.52	810	5.25	39.74
510	12.85	10.76	820	5.31	39.80
520	11.85	12.19	830	5.34	39.83
530	10.61	12.74	840	5.41	39.84
540	9.45	11.66	850	5.49	39.84
550	8.46	9.71	860	5.56	39.82
560	7.67	7.69	870	5.64	39.79
570	7.06	6.18	880	5.74	39.76
580	6.57	5.48	890	5.84	39.72
590	6.18	5.07	900	5.95	39.70
600	5.88	4.65	910	6.08	39.65
610	5.63	4.34	920	6.23	39.60
620	5.48	4.32	930	6.38	39.54
630	5.31	4.47	940	6.56	39.47
640	5.23	4.55	950	6.75	39.38
650	5.13	4.58	960	6.97	39.30
660	5.13	4.60	970	7.23	39.20
670	5.04	4.94	980	7.49	39.08
680	4.98	5.59	990	7.79	38.95

W/L	Standard	Sample	W/L	Standard	Sample
1000	8.12	38.80	1060	11.04	37.46
1010	8.49	38.63	1070	11.62	37.09
1020	8.91	38.44	1080	12.20	36.58
1030	9.37	38.23	1090	12.82	35.94
1040	9.88	38.01	1100	13.75	35.40
1050	10.44	37.74			

Data file:DND RSEX/UVL OFF/UVF OUT/LAU

——— STANDARD Tibbetts 503-305

-- --- LAST SAMPLE 96-J23-7222-125



Report # 97-J23-3204-1 (Solar Heat Reflective Coatings)
UltraScan Specware, Version 1.09 16:03 16:Jan:97
RSEX/UVL OFF/UVF OUT/LAV

STANDARD NAME: Tibbetts 503-305 std
SAMPLE NAME: 96-J23-7222-127
10 DEGREE D65

	STD	SAM
L*	35.03	33.54
a*	-18.38	-20.05
b*	6.51	4.80

DELTA DESCRIPTOR - RECTANGULAR

CIELab THE SAMPLE IS DARKER, GREENER, AND LESS YELLOW

DE*	DC*	DH*
2.81	1.11	2.11

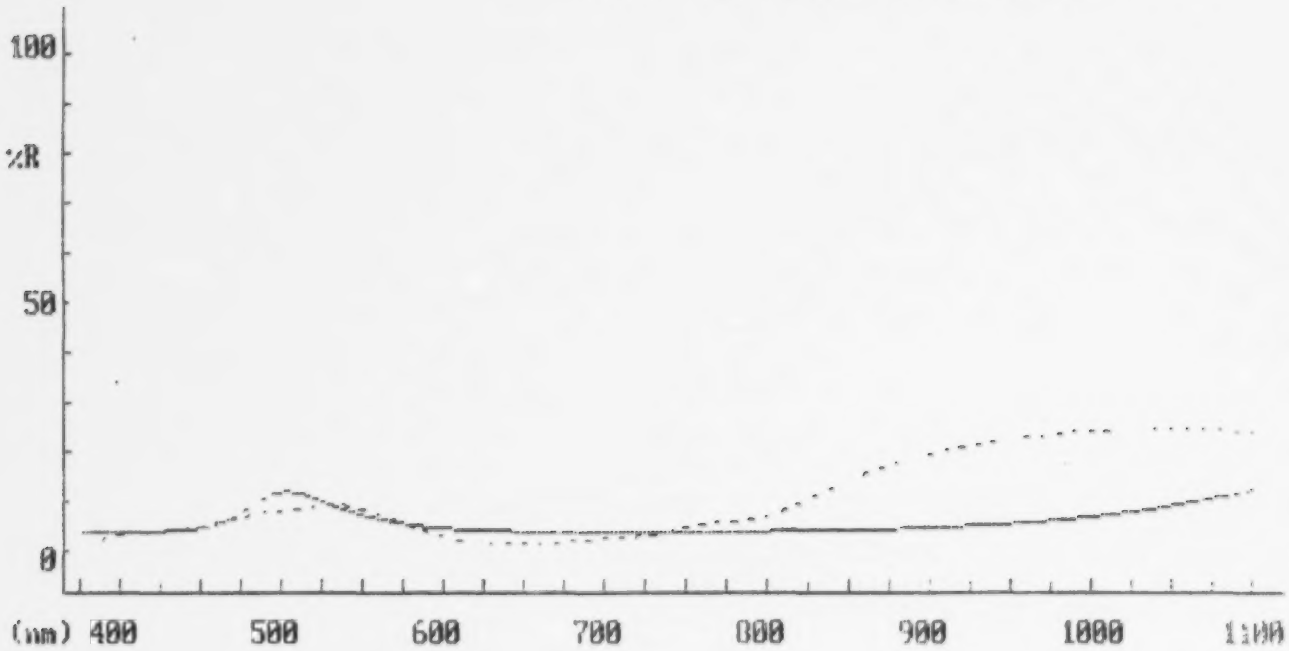
W/L	Standard	Sample	W/L	Standard	Sample
380	4.97	2.69	690	5.00	3.48
390	4.96	3.65	700	5.05	3.79
400	4.95	4.41	710	5.03	4.00
410	5.00	4.82	720	5.00	4.18
420	5.06	5.05	730	5.01	4.44
430	5.23	5.31	740	4.98	4.98
440	5.43	5.69	750	5.08	5.91
450	5.83	6.19	760	5.10	6.56
460	6.59	6.85	770	5.14	6.89
470	7.97	7.64	780	5.15	7.11
480	9.97	8.35	790	5.17	7.50
490	11.95	8.92	800	5.20	8.27
500	13.00	9.35	810	5.25	9.42
510	12.85	9.78	820	5.31	10.81
520	11.85	10.27	830	5.34	12.32
530	10.61	10.57	840	5.41	13.86
540	9.45	10.39	850	5.49	15.33
550	8.46	9.70	860	5.56	16.69
560	7.67	8.65	870	5.64	17.90
570	7.06	7.44	880	5.74	18.96
580	6.57	6.24	890	5.84	19.87
590	6.18	5.10	900	5.95	20.68
600	5.88	4.14	910	6.08	21.39
610	5.63	3.45	920	6.23	22.02
620	5.48	3.08	930	6.38	22.60
630	5.31	2.89	940	6.56	23.11
640	5.23	2.81	950	6.75	23.61
650	5.13	2.76	960	6.97	24.08
660	5.13	2.80	970	7.23	24.47
670	5.04	3.07	980	7.49	24.81
680	4.98	3.23	990	7.79	25.07

W/L	Standard	Sample	W/L	Standard	Sample
1000	8.12	25.30	1060	11.04	25.86
1010	8.49	25.48	1070	11.62	25.74
1020	8.91	25.60	1080	12.20	25.56
1030	9.37	25.69	1090	12.82	25.37
1040	9.88	25.76	1100	13.75	25.47
1050	10.44	25.83			

Data file:DND RSEX/UVL OFF/UVF OUT/LAV

——— STANDARD Tibbetts 503-385

····· LAST SAMPLE 96-J23-7222-127



Appendix J

Sol-Gel Experiments

(7 pages)

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Summary of Powders Prepared

Powder Number*	Sol Composition (% w/w)			Solvent	Solvent/Sol Ratio	Sol/Water Ratio	Comments
	Titanium Isopropoxide	Toluene	Isopropanol				
1S-1	40	20	40	Acetonitrile	5:1	3.3:1	Particle size decreases as solvent/sol
1S-2	40	20	40	Acetonitrile	10:1	3.3:1	ratio increases. All powders too small.
1S-3	40	20	40	Acetonitrile	20:1	3.3:1	
4S-1	57.1	14.3	28.6	Acetonitrile	5:1	2:1	Minor effect of varying sol composition.
5S-1	45.4	18.2	36.4	Acetonitrile	5:1	2:1	Particle size too small and distribution
6S-1	56.8	29.0	14.2	Acetonitrile	5:1	2:1	too narrow.
9S-1	57.1	42.9	--	Acetonitrile	5:1	2:1	Tried, unsuccessfully, to vary stirring rate with 9S-1 and 9S-2.
9S-2	57.1	42.9	--	Acetonitrile	5:1	2:1	Particle size is slightly larger with lower
9S-3	57.1	42.9	--	Acetonitrile	2.5:1	2:1	solvent/sol ratio.
13S-1	57.2	42.8	--	Acetonitrile 95% Water 5%	5:1	--	Powders obtained with water contents of 9% or less, but particle size still too
13S-2	57.2	42.8	--	Acetonitrile 91% Water 9%	5:1	--	small.
13S-3	57.2	42.8	--	Acetonitrile 83% Water 17%	5:1	--	Large, irregularly shaped particles obtained with water contents of >9%.
13S-4	57.2	42.8	--	Acetonitrile 71% Water 29%	5:1	--	
13S-5	57.2	42.8	--	Acetonitrile 50% Water 50%	5:1	--	
13S-6	57.2	42.8	--	Acetonitrile 49% Formamide 47% Water 5%	5 1	--	Upon firing, sample was gray, hard and crystalline. SEM examination revealed sample was not a fine powder.
13S-7	57.2	42.8	--	Isopropanol 95% Water 5%	5:1	--	Spherical particles produced, but size too small
13S-8	57.2	42.8	--	Acetonitrile 48% Isopropanol 48% Water 5%	5:1	--	Spherical particles produced, but size too small.

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Powder Number*	Sol Composition (% w/w)			Solvent	Solvent/Sol Ratio	Sol/Water Ratio	Comments
	Titanium Isopropoxide	Toluene	Isopropanol				
16SA-1	100	--	--	Acetonitrile	5:1	2:1	Least amount of fines in sol using
16SB-1	90	10	--	Acetonitrile	5:1	2:1	100% alkoxide. Generally, particle size
16SC-1	80	20	--	Acetonitrile	5:1	2:1	still too small.
16SD-1	70	30	--	Acetonitrile	5:1	2:1	
16SE-1	60	40	--	Acetonitrile	5:1	2:1	
16SE-2	60	40	--	Acetonitrile 75% Isopropanol 25%	5:1	2:1	Particle size decreases as isopropanol content increases.
16SE-3	60	40	--	Acetonitrile 50% Isopropanol 50%	5:1	2:1	
16SE-4	60	40	--	Acetonitrile 25% Isopropanol 75%	5:1	2:1	
16SE-5	60	40	--	Isopropanol	5:1	2:1	
20S	100	--	--	Acetonitrile	5:1	2:1	Uncalcined particles mostly in desired size range (ca. 500 nm).
21SA-1	100	--	--	Acetonitrile	5:1		This series was prepared primarily for
21SB-1	90	10	--	Acetonitrile	5:1		particle size determination by Malvern
21SC-1	80	20	--	Acetonitrile	5:1		laser light scattering. One sample,
21SC-2	80	20	--	Acetonitrile	10:1		21SC-3, was in the desired particle
21SC-3	80	20	--	Acetonitrile	20:1		size range as determined by Malvern,
21SD-1	70	30	--	Acetonitrile	5:1		but SEM examination revealed the
21SE-1	60	40	--	Acetonitrile	5:1		particles were smaller than desired.
21SF-1	56.9	43.1	--	Acetonitrile	5:1		
23S1-1	80	20	--	Acetonitrile	20:1		Particle size by Malvern indicated these samples were in the desired range, but SEM examination revealed the particles were smaller than desired and contain too many fines.
23S2-1	100	--	--	Acetonitrile	20:1		

Powder Number*	Sol Composition (% w/w)			Solvent	Solvent/Sol Ratio	Sol/Water Ratio	Comments
	Titanium isopropoxide	Toluene	Isopropanol				
26-1	100	--	--	Acetonitrile	4:1	2:1	Reduction of the solvent/sol ratio led to the formation of some larger spheres, but also to a significant quantity of extremely large (>5 µm), irregularly shaped features.
26-2	100	--	--	Acetonitrile	3:1	2:1	
26-3	100	--	--	Acetonitrile	2:1	2:1	
26-4	100	--	--	Acetonitrile	1:1	2:1	
27-1	100	--	--	Acetonitrile 33% Glycerol 33% Isopropanol 33%	7.5:1	2:1	Uncalcined particles approximately 1µm No fines noted.
27-2	100	--	--	Acetonitrile 22% Glycerol 56% Isopropanol 22%	9:1	2:3	Gelling observed upon powder preparation. SEM examination does not indicate powder formation.
29-1	100	--	--	Acetonitrile 25% Glycerol 50% Isopropanol 25%	5:1	1:1	Lumps and opaque material when filtered. Appears gelled upon SEM examination.
29-2	100	--	--	Acetonitrile 14% Glycerol 80% Isopropanol 6%	5:1	1:1	Gelled.
29-3	100	--	--	Acetonitrile 12% Glycerol 87% Isopropanol 1%	5:1	~1:2	Gelled.
29-4	100	--	--	Acetonitrile 33% Glycerol 33% Isopropanol 33%	5:1	2:1	Uncalcined particles approximately 1µm No fines noted. Some particles fused
29-5	100	--	--	Acetonitrile 58% Glycerol 17% Isopropanol 25%	5:1	2:1	Uncalcined particles approximately 1µm Few fines noted. Some particles fused Some irregularly shaped particles.
29-6	100	--	--	Acetonitrile 88% Glycerol 3% Isopropanol 10%	5:1	2:1	Gelled Solvent components may have separated upon sol addition.

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Powder Number*	Sol Composition (% w/w)			Solvent	Solvent/Sol Ratio	Sol/Water Ratio	Comments
	Titanium isopropoxide	Toluene	Isopropanol				
36-1A	100	--	--	Acetonitrile 33% Glycerol 40% Isopropanol 27%	7.5:1	2:1	The glycerol level was increased for this series while the acetonitrile was maintained at 33%. Mixtures were hazy/opaque prior to water addition. Particles tended to be fused and no trend was noticed with increasing solvent/sol ratios. Sample 36-1C was not fully polymerized.
36-1B	100	--	--	Acetonitrile 33% Glycerol 40% Isopropanol 27%	10:1	2:1	
36-1C	100	--	--	Acetonitrile 33% Glycerol 40% Isopropanol 27%	20:1	2:1	
36-2A	100	--	--	Acetonitrile 33% Glycerol 27% Isopropanol 40%	7.5:1	2:1	The isopropanol level was increased for this series while the acetonitrile was maintained at 33% Mixtures were hazy/opaque prior to water addition. Particles tended to be fused and, contrary to what was expected, particle size increased with increased solvent/sol ratios.
36-2B	100	--	--	Acetonitrile 33% Glycerol 27% Isopropanol 40%	10:1	2:1	
36-2C	100	--	--	Acetonitrile 33% Glycerol 27% Isopropanol 40%	20:1	2:1	
39-1 Large Scale	100	--	--	Acetonitrile 33% Glycerol 33% Isopropanol 33%	7.5:1	2:1	SEM examination of uncalcined particles revealed sizes of ~ 1µm, some fused particles and some agglomeration. Calcined particles appeared broken. The particles may have contained residual solvent that expanded during the rapid firing process causing the particles to rupture.

Powder Number*	Sol Composition (% w/w)			Solvent	Solvent/Sol Ratio	Sol/Water Ratio	Comments
	Titanium Isopropoxide	Toluene	Isopropanol				
42-1	100	--	--	Acetonitrile 40% Glycerol 30% Isopropanol 30%	10:1	2:1	In this series, the acetonitrile level was increased. Particle morphology (uncalcined state) shifted from large
42-2	100	--	--	Acetonitrile 61% Glycerol 13% Isopropanol 26%	10:1	~2:1	(~1 µm), fused particles to smaller (<1 µm), discrete particles.
42-3	100	--	--	Acetonitrile 69% Glycerol 6% Isopropanol 24%	~10:1	~2:1	
43-1	100	--	--	Acetonitrile 40% Glycerol 30% Isopropanol 30%	10:1	2:1	In this series, the acetonitrile level was increased and the order of addition to the solvent was changed. Sol was
43-2	100	--	--	Acetonitrile 61% Glycerol 13% Isopropanol 26%	10:1	~2:1	added to the solvent prior to glycerol addition. Generally, the particle morphology (uncalcined state) shifted from large (~1 µm), fused particles to
43-3	100	--	--	Acetonitrile 73.9% Glycerol <0.1% Isopropanol 26.1%	9:1	2:1	small (<<1 µm), discrete particles. Some improvement was noted at intermediate acetonitrile levels (Sample 43-2); the majority of the particles were ~0.8 µm and substantially less fused. However, some lumps were noticed during the preparation of this powder.

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Powder Number*	Sol Composition (% w/w)			Solvent	Solvent/Sol Ratio	Sol/Water Ratio	Comments
	Titanium Isopropoxide	Toluene	Isopropanol				
45-1	100	--	--	Acetonitrile 64% Glycerol 9% Isopropanol 27%	10:1	2:1	This series was performed to determine the effect of organic titanates on particle morphology. The compositions and order of addition were similar to Sample 43-2. Use of the organic titanates did not improve particle morphology. This series also highlighted the technique's sensitivity since Sample 45-1 had fines and more fused particles than Sample 43-2 prepared from a very similar composition.
45-2	100	--	--	Acetonitrile 63% Glycerol 9% Isopropanol 27% TILCOM PI 2: 1%	10:1	2:1	
45-3	100	--	--	Acetonitrile 63% Glycerol 9% Isopropanol 27% TILCOM IA 10: 1%	10:1	2:1	
46-1	100	--	--	Acetonitrile 63 Glycerol 9% Isopropanol 27%	15:1	2:1	This series was performed to determine the effect of organic titanates on particle morphology. The compositions and order of addition were similar to Sample 43-2, but a higher solvent/sol ratio was employed. Use of the organic titanates did not improve particle morphology.
46-2	100	--	--	Acetonitrile 63% Glycerol 9% Isopropanol 27% TILCOM PI 2: 1%	151	2:1	
46-3	100	--	--	Acetonitrile 63% Glycerol 9% Isopropanol 27% TILCOM IA 10: 1%	15:1	2:1	

* All powder numbers are prefaced with 95-J23-7254 or 96-J23-7254

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Summary of Powders Prepared from Titanium Isobutoxide Precursor

Powder Number *	Sol Composition (% w/w)			Solvent	Solvent/Sol Ratio	Sol/Water Ratio	Comments
	Titanium Isobutoxide	Toluene	Isobutanol				
10S-1	57.8	28.3	13.9	Acetonitrile	5:1	6:1	Sol did not emulsify. Powder was obtained from polymerization of minor amount of sol in decanted solvent. Particle size too small.
11S-1	57.6	42.4	--	Acetonitrile	5:1	6:1	Sol did not emulsify. Powder was obtained from polymerization of minor amount of sol in decanted solvent. Particle size extremely small (mostly ≤ 200 nm.

* All powder numbers are prefaced with 95-J23-7254 or 96-J23-7254

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Marine coatings for the hull and superstructure of naval vessels often exhibit relatively high solar absorption due to the dark colours required for visual camouflage. This results in high surface temperatures which reduce the comfort of the crew, increase cooling requirements and amplify the emission of thermal infrared radiation. Reducing the absorption of solar energy requires pigments which reflect strongly in the near infrared. In this project we identified pigments with enhanced infrared-reflective properties, and reformulated three of the most commonly-used CGSB marine colours to produce coatings with improved infrared reflecting properties.

Six variants were prepared for 1-GP-61, 501-109 light grey alkyd enamel. Reflectivity of the experimental formulations at 900 nm ranged from 55% to 81%, compared to 42% for the General Paint standard coating.

Two variants were prepared for 1-GP-200, 501-302 dark grey polyurethane anti-skid enamel. Reflectivity of the experimental formulations at 900 nm ranged from 39% to 44%, compared to 8% for the Tibbetts standard.

Four variants were prepared for 1-GP-200, 503-305 dark green polyurethane anti-sked enamel. Reflectivity of the experimental formulations at 900 nm ranged from 20% to 50%, compared to 5% for the Tibbetts standard.

The experimental coatings meet CSGB requirements for salt spray and accelerated weathering resistance.

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